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DIAGNOSIS

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KEITH A Human embryology and morphology 6th edition, p 533 Arnold & Co, London 1948

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SPINAL CORD VASCULARITY

I Extraspinal sources of spinal cord arteries in man

LEON TVETEN

The arterial supply of the spinal cord is generally described as deriving from two main sources, the vertebro-subclavian arteries and the thoraco lumbar aorta, and occasionally from the iliac and sacral arteries as well Spinal arteries from these vessels enter the intervertebral foramina and, before penetrating the dura mater, divide into three branches, one ventral and one dorsal branch pass to supply the anterior and the posterior part of the vertebral canal, while the middle branch (the radicular artery or arteria nervo medullaris) bifurcates to join the anterior and the posterior nerve roots respectively Some of the root arteries (often called spinal cord tributaries or feeders) extend to the surface of the cord and are interconnected by three longitudinal anastomotic chains, the anterior spinal artery in the midline on the ventral aspect of the cord and the two posterior spinal arteries near the posterior rootlets Rostrally these chains are usually joined by twigs from the intracranial parts of the vertebral arteries Branches from the anterior and posterior spinal arteries ramify on the surface and within the substance of the spinal cord

From the Institute of Pathology, section of Neuropathology University of Oslo, Rikshospitalet, Oslo Norway Submitted for publication 5 December 1974

Since the first description by HALLER (1762) the view has been prevailing that th vertebral artery provides the main supply of the cervical spinal cord Most author also agree that an additional supply may be derived from other branches of the sub clavian artery, among these the thyreocervical and the costocervical trunks are con sidered to be the most important The spinal tributaries from these two trunks, how ever, are often depicted differently in schematical drawings, and opinions vary a to their relative importance (TUREEN 1938, GILLILAN 1958, VIRASWAMI 1963, JEL LINGER 1966, LAZORTHES et coll 1966 a, and CHAKRAVORTY 1970) In a recent repor FRIED et coll (1970) suggest that the significance of the vertebral artery has prev ously been overemphasized and ascribe particular importance to the contributior from the costocervical trunks It should be noted, however, that most of the previou observations have been made on isolated spinal cords and that, in such case the exact origin of the spinal tributaries may be difficult if not impossible t determine

Less controversy exists concerning the sources of feeding vessels to the thorac lumbar and lower cord, most of the blood supply usually deriving from the aort segmental arteries However, important feeders to the cord have also been describe arising from the iliac and the sacral arteries (DESPROGES GOTTERON 1955, DESEZE coll 1957, GILLILAN, LAZORTHES et coll 1966 b)

The significance of variations in the origin and branching of the intercost arteries on the spinal cord circulation have, however, not been thoroughly invest gated GILLILAN states that two or more segmental arteries may occasionally branc from a common stem but does not believe in any functional consequences

Absence of an intercostal or a lumbar artery has occasionally been reported an it has been stated that, in such cases, the bony structures are supplied by the adja cent segmental arteries (SOLOTUCHIN 1933, FORSSMAN & PETREN 1938), but no com ment has been made as to the arrangement of the radicular arteries

Opinions also vary with regard to the number of spinal arteries entering eac intervertebral foramen CLEMENS (1966) claimed that the artery is always singula and may even be absent at some levels, while other authors maintain that two o three arteries from different sources will often enter the same foramen and intercon nect before dividing into regular branches (VIRASWAMI, CHAKRAVORTY)

It is generally agreed (TORR 1957) that injury to a segmental artery contributin to the spinal cord circulation entails the risk of ischaemic myelopathy increasin with the number of vessels involved With this practical implication in mind, th present investigation was undertaken in an effort to further elucidate (1) the origi of the arterial spinal branches and tributaries to the cervical spinal cord and (2 variations in the origin and branching of the aortic segmental arteries in relation t the spinal cord blood supply below the cervical part

The observations were made on intact spinal cords using the combination o radiography and stereomicroscopy This permitted a clear demonstration of the con nections between the extra and intraspinal arteries

Material and Methods

The material comprised 30 human infants chosen at random, ranging from 7 months of fetal life to 6 months of age The human vascular system is well developed before six months of fetal life and no significant changes appear thereafter in the spinal cord (TORR, GILLILAN) No signs of cardiovascular or neural lesions were disclosed in the material

Injection technique At autopsy the visceral branches from the aorta were ligated The internal organs were removed with the exception of the brain with the brainstem and spinal cord, as well as the heart and the aorta with its main branches Ligatures were applied to the axillary arteries and the distal part of the common iliac arteries and the body was placed in warm (37–38°C) physiologic saline for about one hour A polyethylene catheter of a calibre just large enough to fit into the proximal part of the ascending aorta was introduced through the left ventricle With the body still submerged an 80% aqueous suspension of the contrast medium (Chromopaque Blue Damancy & Co, England) with 4% formalin and 10% gelatine was injected at a pressure of 150 to 160 mm Hg Immediately before injection the inferior and superior caval veins were cut open to allow the blood to escape A total amount of 300 to 500 ml of contrast medium was injected, the procedure was accomplished in about half an hour A discoloration of the tongue and the skeletal muscles usually indicated satisfactory filling of the extra and intraspinal arteries Formalin accelerated the hardening of the contrast gelatine suspension, in addition to producing a favourable fixation of the tissue

Radiographic technique Immediately after injection a p a film was exposed Following a complete laminectomy, the rest of the vertebral column with the aorta and its main branches was removed and deposited overnight in 10% formalin solution P a and lateral views of the specimens were obtained before and after removal of the aorta Following decalcification in 7% nitric acid with 1% urea, further films were exposed in order to demonstrate more clearly the connections between the extra and the intraspinal arteries

In some specimens the spinal cord was removed with the dura intact and subjected to radiography in p a and lateral projections and then cross sectioned into pieces of one or two segments These pieces were subjected to further radiography and later made transparent by the method described below The results obtained in the latter investigation are reported elsewhere (TVETEN to be published)

A Philips tube with 0 4 mm × 8 mm focus, equipped with a copper anode and a beryllium window was used, exposure data 30 to 55 kV, 15 to 25 mA, 30 to 45 min depending upon the thickness of the specimen FFD 150 cm The specimens were placed in contact with a fine grain film (Kodalith Orto Type 3) in thin polyethylene bags

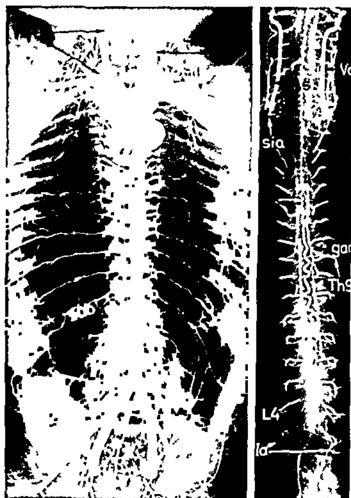


Fig 1 Radiography Extraspinal sources of spinal cord arterial supply Whole body left, decalcified column with intact spinal cord right The aorta (A), common carotid artery (Ca) vertebral artery (Va) ascending cervical artery (As), superior intercostal artery (sia) subcostal artery (sub) ileolumbar artery (Ia), median sacral artery (Ms), anterior spinal artery (→), great anterior root artery (gar) arising at Th9 on the left side

Clearing technique Following the radiographic procedures the vertebral column with or without the spinal cord was made transparent by the technique of Spalteholz (CULLING 1963) A slight modification of the method was made to avoid loss of colour intensity of the contrast medium bleaching of the specimen was performed with a reduced concentration of hydrogen-peroxide (3 % vol instead of the recommended 10 % vol for 2 to 3 days)

The three dimensional view of the vascular system obtained by stereomicroscopy of the transparent specimen not only served as a correlate to the radiographic findings, but also made possible a more detailed examination of the minute vascular relations

Results

Adequate filling of the neck arteries was obtained in 27 of the 30 cases and of the lumbo-sacral arteries in 28 cases The arteries of the thoracic region were always adequately filled (Fig 1)



The vertebral artery, invariably originating from the first part of the subclavian artery, in one specimen on the right side entered the transverse foramen of the fifth cervical vertebra, in the rest that of the sixth As the artery ascended through the transverse foramina of the upper six cervical vertebrae, spinal branches were regularly distributed, one through each of the intervertebral foramina, occasionally also one through the intervertebral foramen between the sixth and the seventh cervical vertebra These branches followed the ventral surface of the nerve trunk A similar branch from the ascending cervical artery was invariably found on the dorsal surface of the nerve trunk from the sixth to the third, occasionally also the second, cervical segments The position of the two branches in relation to the nerve trunk, as evident on cross-sections of the cervical column, seemed important in identifying the vessels (Fig 2) Before giving rise to the radicular artery the two branches were interconnected on many points outside the dura mater (Fig 2)

The ventral branch of the spinal artery of the upper 6 or 7 cervical segments was invariably supplied by the vertebral artery It extended to the posterior surface of the vertebral body dividing into longitudinal and transverse branches which anasto-

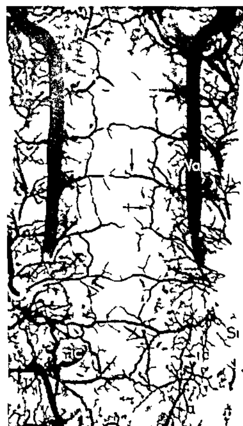


Fig 3



Fig 4

Fig 3 Dorsal view of the cervical region of a transparent specimen Longitudinal (—>) and transverse (<—>) arterial anastomoses between spinal branches on the posterior surface of the vertebral bodies Interconnections (c) between spinal branches from the first aortic intercostal (ai) and the superior intercostal (si) arteries entering the same intervertebral foramen Vertebral artery (Va)

Fig 4 Radiography Single ventral feeder (rC7) to the cervical spinal cord at C7 arising from the vertebral artery (Va) Deep cervical artery (Pa) the sixth cervical vertebral body (Vb6)

mosed with corresponding branches from above and below as well as from the opposite side (Figs 2 3)

The posterior branch of the spinal artery in the cervical region however mainly derived from the ascending cervical artery (Fig 2) These branches interconnected on the posterior surface of the vertebral canal similarly to those on the dorsal surface of the vertebral body

Most of the radicular branches from the vertebral artery were small and ramified on the nerve roots and into the substance of the dorsal root ganglions Only a limited number extended to the surface of the spinal cord along the nerve roots However more than half the number of ventral feeders to the cervical spinal cord derived from the vertebral artery and in 5 instances the vertebral artery was the only source of blood supply to the cervical cord In 2 of these cases only one significant ventral root artery to the cervical enlargement (C4 Th1) existed and this joined the sixth and seventh cervical nerve roots respectively (Fig 4) Most often the tributa

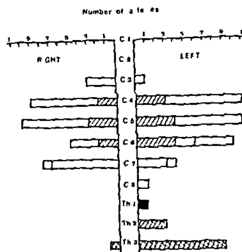


Fig 5 Origin and distribution of ventral ar-

... artery ■ Superior intercostal artery
□ Aortic intercostal artery

ries from the vertebral artery ran along the C4 and C5 nerve roots, less frequently along the C6 and C3 roots (Fig 5)

In 2 cases the right vertebral artery had a diameter of half or less than half of the left one (Fig 6) In one of these the ipsilateral ascending cervical artery contributed with a large branch to the mid cervical region of the cord (Fig 6), while in the second case a similar branch came from the opposite vertebral artery

Outside the vertebral column lateral branches from the vertebral artery connected profusely with small branches from other arteries in the neck

The ascending cervical artery deriving from the thyreocervical trunk ascended in front of the transverse process of the 6–7 to the 2–3 cervical vertebrae (Fig 7) It gave off branches to the upper 4 or 5 intervertebral foramina The spinal branches anastomosed with corresponding branches from the vertebral artery as described previously and not infrequently the ascending cervical artery gave rise to significant ventral feeders in the upper part (C4–C6) of the cervical enlargement (Fig 5)

The costocervical trunk branched from the dorsal surface of the subclavian artery distal to the origin of the vertebral artery and divided into the deep (or profound) cervical artery and the superior (or highest) intercostal artery

The deep cervical artery passed backwards between the transverse process of the seventh cervical vertebra and the neck of the first rib giving off branches to the foramen between the sixth and the seventh cervical vertebra and also to that between the latter and the first thoracic vertebra (Fig 7) These branches were reinforced by spinal twigs from the vertebral artery and from the superior intercostal artery, respectively



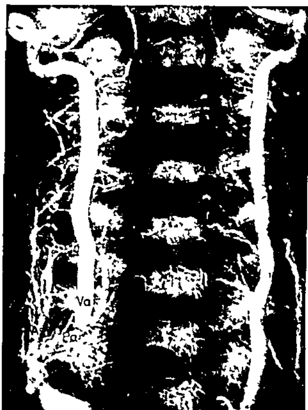


Fig 6

Fig 7

Fig 6 Radiography Hypoplasia of the right vertebral artery (Va) A conspicuous ventral feeder (rC5) at C5 branches from the ascending cervical artery (As) to join the anterior spinal artery (asa) which divides into two branches immediately below the point of junction Common carotid artery (Ca) spinal cord (Sp)

Fig 7 Radiography of neck arteries contributing to the supply of the spinal cord Vertebral artery (Va), ascending cervical artery (As) deep cervical artery (Pa), the sixth cervical vertebral body (Vb6)

The vast majority of tributaries in the lower two-thirds (C6–Th1) of the cervical enlargement was derived from the deep cervical artery (Fig 5) In 2 of 4 cases with a single radicular artery to the ventral surface of the cervical cord, the feeder came from the deep cervical artery and followed the C7 nerve root (Fig 8) As a rule, tributaries in the lower part of the cervical region were comparatively wide, though the calibre evidently varied with the number of feeding vessels

The superior intercostal artery descended on the posterior wall of the thoracic cavity in front of the neck of the ribs (Fig 9) It divided into one ventral and one dorsal branch in the upper one or two, rarely three, intercostal spaces The dorsal branch gave rise to the spinal artery, which after penetrating the intervertebral foramen divided in the regular way The lower spinal branch from the superior intercostal artery was usually reinforced by a twig from the first aortic intercostal artery entering the same foramen (Fig 3) As a rule, the artery on the right side



Fig 8



Fig 9

Fig 8 Radiography of serial cross-sections of the lower cervical region A spinal cord tributary (sct) from the deep cervical artery (Pa) running along the C7 anterior nerve root Subclavian artery (Sa), vertebral artery (Va), spinal cord (sp), vertebral body (Vb)

Fig 9 Radiography of the upper thoracic region A common stem (cs) of three posterior intercostal arteries on both sides A posterior spinal cord tributary (↔) branching from the common stem to join the posterior spinal artery (psa) Subclavian artery (Sa), highest intercostal artery (sia), anterior spinal artery (asa)

supplied the upper two intercostal spaces while that on the left side usually furnished the first space only In three cases the arteries were symmetrically arranged in the first intercostal space In one case regular branches were distributed to the upper three spaces on the right and the upper two on the left side

The root arteries deriving from the superior intercostal artery were usually small, soon ramifying to the dorsal root ganglions and nerve roots A significant ventral feeder to the first thoracic segment was observed in one case only, those entering the thoracic cord below this level were all derived from aortic intercostals

In accordance with the arrangement of the superior intercostal artery *the aortic*



Fig 10 Radiography of the lower thoracic and upper lumbar region Absence of the right subcostal artery, the spinal branch being supplied from the first lumbar artery (arrow) The left subcostal artery (su) furnishes the dorsal branch only The right 10 and 11 intercostal arteries arise on a common stem (cs)

intercostals (posterior intercostal arteries) numbered usually ten on the left side and nine on the right, each dividing into one ventral and one dorsal branch In 3 specimens the first aortic intercostal artery was represented by its proximal part plus the dorsal branch only, while the ventral branch was derived from the superior intercostal artery of the costo cervical trunk In about one third (9/30) of the cases 2, occasionally 3, aortic intercostals branched from a common stem This variety mainly existed in the upper half of the thoracic cavity, about twice as often on the right as on the left side, in 3 specimens occurring both in the upper and lower thoracic region, on the same or the opposite side In one specimen a common stem of 3 aortic intercostals was observed at the same level on the right and the left side (Fig 9) Such vascular variations indicate that a single aortic segment not infrequently supplies 2, sometimes 3 spinal segments However, with regard to the supply of the spinal cord, a significant ventral feeder was never observed in the area supplied by aortic intercostals arising from a common arterial stem, while posterior root arteries extending to the dorsal surface of the cord were frequently found (Fig 9)

The subcostal arteries form the last pair of segmental arteries from the descending thoracic aorta being located below the twelfth rib Most often the vessels divided in the regular way, similar to the intercostal arteries In one fifth (6/30) of the cases,

however, the subcostal artery supplied the dorsal branch only, the ventral being supplied by the lowermost intercostal or the first lumbar artery This variety was unilateral in 4 specimens, bilateral in another 2 In 2 further cases the subcostal artery on one or the other side was absent and substituted by branches from the segmental artery above or below (Fig 10) The spinal branch at the site of such variations in the subcostal space was invariably small, giving off tiny radicular arteries soon ramifying on the nerve roots Variations in the branching of the lower intercostal and the subcostal arteries are important to consider because of the frequent occurrence of significant spinal feeders arising from these vessels, as emphasized in another report (TVETEN to be published)

The lumbar arteries form five pairs, the upper four arising from the dorsal surface of the aorta while the fifth pair branched from the lateral sacral artery or the ileo lumbar artery, rarely from the median sacral artery (Fig 1) The dorsal branch from the upper 2 or 3 lumbar arteries often was a prominent vessel which not infrequently gave off branches to the dorsal, occasionally also to the ventral part of the cord The spinal branch of the lower 2 or 3 lumbar, ileolumbar and sacral arteries supplied mainly the dorsal root ganglions and the roots of the cauda equina

At each level of the thoracic, lumbar and sacral regions the segmental arteries interconnected both in the longitudinal and the transverse direction inside as well as outside the vertebral canal

The ventral branches from the intercostal arteries were also connected with the intercostal branches from the internal mammary arteries (anterior intercostal arteries), the upper lumbar arteries anastomosed with branches from the superior and inferior epigastric arteries Arteries from the lower lumbar aorta anastomosed with the ileolumbar arteries and other arteries in the pelvic region

DISCUSSION

The present investigation demonstrated that the upper part of the cervical cord segments (C1–C3) were supplied by the vertebral artery, the middle cervical segments (C4–C6) by the vertebral or the ascending cervical artery, while the bottom segments (C7–Th1) were supplied mainly from the costo-cervical trunk This distribution tallies fairly well with that reported by NOESKE (1958) and by VIRASWAMI, but is at variance with that by GILLILAN who believed that any neck artery in the vicinity could give rise to the cervical radicular arteries Contrary to the present observations, CHAKRAVORTY observed that the sixth cervical segment was always supplied by the vertebral artery, while the radicular arteries of the seventh and the eighth cervical segments were always derived from the costo-cervical trunk

FRIED et coll believe that the vascular arrangement of the cervical spinal cord in the monkey is identical with that in man they maintain from observations of the former that the costo-cervical trunk provides the main blood supply for the cervical

cord However, their material only consisted of 5 monkeys, and as there are considerable individual variations, the conclusion should be regarded with caution

On the other hand, in agreement with FRIED et coll, observations in the present material indicate that a large radicular artery is often present in the low cervical region in man, usually accompanying a C6 or C7 anterior nerve root, but it should be emphasized that this artery is not a constant branch of the costo-cervical trunk as these authors maintain

In the present series all ventral feeders entering the sixth cervical segment of the cord came either from the vertebral or from the ascending cervical artery while those of the seventh cervical segment were derived mainly from the costo-cervical trunk, in rare cases even from the vertebral artery Thus in one of the 4 cases with a single ventral feeder to the cervical cord, the artery branched off from the vertebral artery joining the C7 nerve root MANNEN (1964) points to the paucity of cervical cord tributaries in a comparatively large number of humans, 45 of 235 cases displaying one single feeder which usually followed the sixth cervical anterior nerve root However, the observations were made on isolated spinal cords and the exact origin of the spinal cord feeders was not determined

Since the first description by ADAMKIEWICZ (1882) most authors agree that the radicular arteries are the most important feeders to the cervical spinal cord circulation, although some authors (METTLER 1948, ZULCH 1962, HENSON & PARSONS 1967) still believe that the supply is primarily derived from the spinal branches of the intracranial part of the vertebral artery

The poor supply of radicular arteries to the upper thoracic cord has been stressed by many authors (for ref see JELLINGER) This region corresponds to the area mainly furnished by the superior intercostal artery coming from the costo-cervical trunk

The classical description of nine pairs of aortic intercostal arteries distributed segmentally from the third to the eleventh intercostal spaces dividing into a ventral and a dorsal branch was confirmed only in about two fifths of the present human cases The frequent occurrence of 2, occasionally 3, aortic intercostals from a common stem was remarkable In an investigation of the spinal cord circulation following interruption of the intercostal arteries post mortem, TORR does not comment on this fact although it is clearly visible in the low thoracic region in his illustration, Figure 16 GILLILAN mentions it but claims that it has no clinical significance However, it is generally agreed that injury to segmental arteries contributing to the spinal cord circulation entails the risk of ischaemic myelopathy, the danger increasing with the number of vessels involved The fact that in the present material no significant ventral feeder to the cord was ever observed in the distribution region of intercostals arising on a common stem, certainly favours the view of GILLILAN On the other hand, the posterior feeders to the cord must also be borne in mind They were not infrequently present at the level of the vascular anomaly and interruption of blood flow in them may, at least theoretically, give rise to posterior spinal cord infarction

Variations in origin and branching of the subcostal arteries were comparatively frequent in the present human series The importance of considering such variations lies in the fact that not infrequently large arterial tributaries to the lumbosacral cord arise from the subcostal space (JELLINGER) However, the existence of a rudimentary aortic subcostal artery with no ventral branch, indicates that no significant spinal cord feeder arises from this side of the space This probably reflects a natural means of protection since the capacity of the collateral supply available is evidently reduced by the absent connection between the subcostal artery and other arteries on the postero-lateral body-wall, such as the inferior epigastric artery

The arrangement of anastomoses between the extraspinal arteries has been extensively described previously VIRASWAMI and LAZORTHES et coll (1966 a) provided details about the neck arteries and stressed the importance of anastomoses between the vertebral artery and the segmental collaterals of other arteries such as the deep cervical artery and the ascending cervical artery These authors believed that obstruction to an artery of the cervical cord may be readily compensated by other neck arteries and were able to demonstrate this both clinically (LAZORTHES et coll 1966 a) and experimentally (VIRASWAMI, LAZORTHES et coll 1966 a) The present results support this view The two vertebral arteries interconnected profusely both directly by way of basilar, radicular and spinal arteries, and indirectly by way of midline connections between the other neck arteries Thus, in the case of an obstructive lesion of the proximal part of the vertebral artery, numerous collateral pathways may be brought into operation

It is well evidenced by previous authors that the segmental arteries of the cervical, thoracic and lumbo sacral regions are interconnected inside as well as outside the vertebral canal, forming longitudinal anastomotic chains along the entire length of the vertebral column and also midline connections within and on the surface of the vertebral bodies The functional significance of these anastomoses is not known LAZORTHES (1972) believes that the collateral pathways are smallest and least numerous in the mid thoracic region (Th4–Th7) This part of the spinal cord is by ZULCH (1954) considered to be particularly vulnerable to ischaemic injury JELLINGER, on the other hand, claims that the lower cervical and the upper thoracic segments of the spinal cord are most often involved in patients with general haemodynamic disturbances and that the lesions in a large number of cases correspond to the anatomic border between the two main sources of spinal cord arterial supply, the vertebro-subclavian arteries and the aorta The functional and the anatomic borders are not always the same because a great number of intra as well as extraspinal connections between the two main sources exist The fact that the lower spinal branch of the superior intercostal artery is invariably reinforced by a spinal branch from the first aortic intercostal as pointed out by VIRASWAMI and confirmed in the present material, suggests that other factors, e g the local need of blood supply and local haemodynamics are of great importance for the development of ischaemic myelopathy following a general vascular impairment

SUMMARY

The arrangement of extraspinal sources of the spinal cord arterial supply in man is more complicated than previously described, especially with regard to the origin and branching of the aortic segmental arteries The fact that other arteries in the neck than the vertebral artery, such as the costo-cervical trunk and the ascending cervical artery may contribute to the supply of the cervical cord is confirmed, and also the occurrence of two or more spinal branches from different sources entering the same intervertebral foramen Frequent occurrence of two or more segmental arteries arising from a common stem and variations in the branching of the subcostal arteries were found, their functional significance on the spinal cord circulation is not known The fact that no significant anterior root artery was ever seen at the level of the vascular anomaly suggests that the anomaly is of no clinical importance Nevertheless, obstruction of a common stem may entail the risk of spinal cord infarction due to involvement of an important posterior root artery On the other hand, the spinal cord seems to be fairly well protected against ischaemic injury following limited interference with the extraspinal arteries due to a profuse supply of intra- and extraspinal collaterals

ZUSAMMENFASSUNG

Die Anordnung extraspinaler arterieller Versorgungsquellen der Wirbelsaule beim Menschen ist komplizierter als zuvor beschrieben, besonders hinsichtlich des Ursprungs und der Verzweigung der Segment Arterien von der Aorta Die Tatsache, dass im Nacken andere Arterien als die Vertebral-Arterie, wie der costo-cervicale Stamm und die aufsteigende Cervikal Arterie zur Versorgung der Halswirbel beitragen konnen, wird bestatigt, ebenfalls das Vorkommen von zwei oder mehr Spinalasten von verschiedenen Quellen, die durch dasselbe Intervetebral Foramen treten Das haufige Vorkommen von zwei oder mehr Segment-Arterien, die von einem gemeinsamen Stamm ausgehen, und Abweichungen in der Verzweigung der Subcostal Arterien wurden festgestellt, deren funktionelle Bedeutung fur die Blutversorgung der Wirbelsaule ist nicht bekannt Die Tatsache, dass niemals eine signifikante vordere Wurzelarterie auf dem Niveau von Gefassanomalien gesehen worden ist, lasst vermuten, dass die Anomalie ohne klinische Bedeutung ist Dennoch mag eine Obstruktion eines gemeinsamen Stamms das Risiko einer Infarzierung der Wirbelsäule infolge Beteiligung einer wesentlichen hinteren Wurzel Arterie zur Folge haben Auf der anderen Seite scheint die Wirbelsaule ziemlich gut gegenuber ischamische Schaden im Anschluss an eine begrenzte Beeintrachtigung der extraspinalen Arterien infolge einer reichen Versorgung durch intra und extraspinale Kollateralen geschutzt zu sein

RESUME

La disposition des sources extra spinales de la vascularisation artérielle de la moelle epinière chez l homme est plus compliquée que ces descriptions antérieures, particulièrement en ce qui concerne l origine et les divisions des artères segmentaires aortiques Le fait que dans le cou d autres artères que l artère vertébrale, telles que le tronc costo cervical et l'artere cervicale ascendante peuvent contribuer a l irrigation de la moelle cervicale est confirme ainsi que la possibilite que 2 ou plusieurs branches spinales provenant de différentes sources pénetrent par le meme trou de conjugaison Il est fréquent que 2 ou plusieurs artères segmentaires proviennent d un tronc commun et presentent des variations dans les ramifications des artères spino costales, leur importance fonctionnelle pour la circulation

de la moelle est inconnue Le fait qu'on n'a jamais vu d artère radiculaire antérieure im portante au niveau de l anomalie vasculaire fait penser que cette anomalie est sans importance clinique Cependant, l'obstruction d un tronc commun peut comporter un risque de ramollissement de la moelle par atteinte d une importante artere radiculaire postérieure D'autre part, la moelle paraît assez bien protegée contre les lésions ischémiques consécutives à une atteinte limitee des artères extra spinales, grâce a de nombreuses collaterales intra- et extra spinales

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SECRETIN AND EPINEPHRINE COMBINED IN CELIAC ANGIOGRAPHY

ROLF UDÉN

Various pharmacodynamic substances have been used to enhance pancreatic angiography The effect of epinephrine in celiac angiography is described among others by BOIJSEN & REDMAN (1967), KAHN et coll (1967) and KAUDE & WIRTANEN (1970)

Vasoconstriction of the hepatic, gastric and splenic arteries is produced by intra-arterial epinephrine administration No definite vasoconstriction can be detected in the gastroduodenal artery, the pancreaticoduodenal arteries or in the pancreatic arteries arising from the celiac trunk or the splenic artery There is no effect of epinephrine on the collateral arteries to the superior mesenteric artery

Secretin increases the blood flow rate through the pancreas and duodenum as well as the width of the pancreatic and duodenal vessels so that more contrast medium may be injected during a shorter time and produce a more accurate examination In particular the accumulation of contrast medium during the capillary phase—'the pancreatographic effect'—and the venous phase were enhanced and as a consequence small normal pancreatic veins and small pathologic tumour veins were filled with medium (UDÉN 1969)

Following intra arterial administration of epinephrine in the celiac axis the contrast medium is directed to pancreas and duodenum and after secretin the blood flow through the pancreas increases Consequently a combination of these two agents in celiac angiography would improve pancreatic angiography

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The present investigation was carried out during the period 1969 to 1972 to ascertain the combined effect of secretin and epinephrine in pancreatic angiography and to see whether it would assist in reaching a diagnosis

The vessels in a pancreatic tumour are described by most authors as very small vessels of abnormal course, often with sharp angulation, increased tortuosity and irregular caliber Opinion about the nature of these vessels differs greatly LUNDERQUIST (1965), OLSSON (1970) and TYLÉN (1973) consider them to be newly formed, as does UDÉN (1969) BÜCHELER et coll (1971) also described arteriovenous fistulas as a typical finding in carcinoma of the pancreas

Other authors such as GOLDSTEIN et coll (1974) and BOOKSTEIN et coll (1969) are of the opinion that some of these vessels probably represent neovascularity, and others represent pre-existing vessels with encasement MARIONS (1974) states that carcinoma of the pancreas is avascular and there are no newly formed vessels to be found even at the most thorough microscopy and that the vessels in a tumour are widened and stenosed pre-existing vessels

In parallel with the different opinions on the nature of the vessels, the nomenclature is abundant, pathologic, tumour, newly formed, neoplastic, widened and stenosed pre-existing vessels and neo-vascularity As the nature of the vessels in a tumour does not seem to be quite clear and as the names allude to the nature, the more neutral expression, abnormal (arteries, capillaries and veins), will be used

The material consisted of 39 patients aged between 38 and 75 with a mean of 61 years and made up of 22 men and 17 women The patients were examined for possible or probable malignancy of the pancreas or the liver The final diagnoses were based on clinical examinations, laboratory tests, surgery and autopsy

Six patients had carcinoma of the pancreas and two had metastases in the pancreas, one from carcinoma of the uterus and one from the lung Two patients had metastases behind the pancreas, one from a carcinoma of the colon and one from a primary carcinoma of the liver

Nine patients had pancreatitis, two of them with acute exacerbations One patient had a Schwannoma in the duodenal wall The pancreas was normal in 19 patients Of these patients, however, one had a carcinoma of the lung, two of the stomach, one of the gall-bladder and one had a primary carcinoma of the liver Two had choledocholithiasis with inflammation in the vicinity Altogether 12 patients had liver metastases

Methods

Angiographic technique and the administration of secretin and epinephrine Selective angiographies were performed with MIKAELSSON (1955) catheters inserted after puncture of the femoral artery

In all 39 cases one angiographic series was performed without pharmacodynamic

substances and one with secretin and epinephrine Between these a further series was performed in 32 cases, in 23 with secretin and in 9 with epinephrine Secretin, 90 to 150 clinical units, was injected through the catheters 1½ to 2 min before the injection of contrast medium and 4 to 6 μg of epinephrine 15 to 20 s before the contrast medium

Terminology and abbreviation Series 0 angiography without additional pharmaceuticals Series S angiography with secretin Series E angiography with epinephrine Series SE angiography with secretin and epinephrine

Combinations of series in the material Alternative 1 series 0 and SE (39 patients) Alternative 2 series 0, S and SE (23 patients) Alternative 3 series 0, E and SE (9 patients)

Alternatives 2 and 3 are subsets of alternative 1 and thus only series 0 and SE were performed in 7 patients

The film series were programmed as follows In series 0 and S, 2/s for 4 seconds, 1/s for 3 seconds and 1/s every third second for 15 seconds In series E and series SE 1/s for 6 seconds and 1/s every two seconds for 20 seconds

For each angiography 30 to 40 ml of Isopaque Coronar were injected at a rate of 12 to 15 ml/s in series 0 and S In series E and SE 15 to 20 ml Isopaque Coronar were injected at a rate of 6 to 7 ml/s

Celiac angiography was performed in all, and two examinations of the series 0 were performed as a combined celiac and superior mesenteric angiography

Before the examination the stomach was often inflated with carbon dioxide Premedication with 5 mg Valium was sometimes given

Recording of the vascularity The size of the arteries was estimated by measuring the diameter of the gastroduodenal artery, the left or right hepatic artery and the splenic artery The diameter of the gastroduodenal artery was recorded 1 cm from its origin, the measurements being made in the first film in which filling of a small pancreatic artery was obtained in each series, the diameter of the other arteries was determined on the same film

The number and width of the small pancreatic arteries and the accumulation of contrast medium in the pancreas during the capillary phase, the pancreatographic effect, were estimated and classified in degrees of 1 to 4, from *slight* to *prominent*, and used as parameters for the capillary phase The regions of the head and the tail of the pancreas were recorded separately because they are supplied by different vessels

The diameter of the portal vein and the splenic vein was measured to determine the size of the veins The contrasting effect of the veins was also estimated and classified in degrees of 1 to 4 and compared between the series The contrasting effect of the choledochal vein (PETRÉN 1933, UDÉN 1972) was also estimated in the same way

The attenuation of radiation by a vessel depends on its width and on the concen-

tration of the contrast medium contained in it Common expressions are contrast density, opacification and contrast filling, which are terms without reference in a roentgenogram The expression 'contrasting effect' more correctly denotes this attenuation and will be used subsequently

Blood flow The arterial filling phase and the arterial phase (GREITZ 1956, UDEN 1969, 1972) were determined in the liver, pancreas and spleen The time necessary for maximum contrasting effect of the portal or the splenic vein was also registered

The angiographic appearances of carcinoma of pancreas have been described by LUNDERQUIST (1965) as (1) displacement of arteries, (2) stenosed arteries, (3) newly formed pathologic arteries (here called abnormal arteries) and (4) accumulation of contrast medium within the tumour during the capillary phase (here called contrasting effect of the tumour) These signs were recorded and estimated in degrees of 1 to 3, from slight to prominent In the same way abnormal veins (UDEN 1969) and deformed smaller veins as the choledochal vein or the common hepatic vein (UDEN 1972) and the pancreaticoduodenal vein were recorded (Fig 5)

Results

Influence of secretin and epinephrine on vascularity and blood flow

Pancreas circulation

Normal pancreas and malignancy of pancreas (30 patients) After secretin and epinephrine, the circulation through the pancreas, particularly in the head, usually increased In the tail, the increase was only moderate The width of the gastroduodenal artery increased in the mean from 3 5 to 4 3 mm and the number and width of the small pancreatic arteries in the head increased in 26 of the 30 cases, were equal in 2 and decreased in 2 The pancreatographic effect in the head increased in 20, was equal in 7 and decreased in 3 The arterial filling phase of the gastroduodenal artery was in the mean 1 2 seconds in series 0 and 1 3 seconds in series SE (Table 1) The number and width of the small pancreatic arteries in the tail increased in 20 cases were equal in 5 and decreased in 5, and the pancreatographic effect of the tail increased in 17, was equal in 7 and decreased in 6

In the 7 patients, examined as alternative 3, the diameter of the gastroduodenal artery increased from series E to series SE in every case, in the mean from 3 6 mm to 4 4 mm, and the arterial filling phase decreased in all cases, in the mean from 1 9 to 1 3 seconds (Table 1) In the head of the pancreas the number and width of the small pancreatic arteries and the pancreatographic effect increased from series E to series SE in every case and often in the tail (Fig 1)

Table 1

Effect of secretin epinephrine, and secretin and epinephrine combined on the diameter and the arterial filling phase of the gastroduodenal artery in 39 celiac angiographies Mean values (range values in parenthesis) Series 0 without pharmaceuticals Series E with epinephrine Series S with secretin Series SE with secretin and epinephrine

Series	Diameter (mm)				Arterial filling phase (s)			
	0	S	E	SE	0	S	E	SE
Normality or malignancy								
Alt. 1 (30)	3 5	—	—	4 3	1 2	—	—	1 3
	(2 5 5)	—	—	(2–6)	(1–3)	—	—	(1–2)
Alt 2 (16)	3 7	4 3	—	4 3	1 2	0 9	—	1 3
	(2 5–5 5)	(3–6)	—	(2–6)	(1–3)	(0 5–1 5)	—	(1–2)
Alt. 3 (7)	3 0	—	3 6	4 4	1 2	—	1 9	1 3
	(2 0–4 5)	—	(2 0–4 5)	(3 5 5)	(1–3)	—	(1–3)	(1–2)
Pancreatitis								
Alt 1 (9)	3 5	—	—	3 0	1 4	—	—	4 7
	(1 5–4)	—	—	(1 3)	(1–3 5)	—	—	(1–13)
Alt 2 (7)	3 6	4 2	—	3 1	1 2	1	—	4 6
	(3–5)	(3 5–6)	—	(2 5–6)	(1 1 5)	(1)	—	(1–13)
Alt 3 (2)	3	—	1 8	2 3	2 3	—	3 5	5
	(1 5–4 5)	—	(0 5–3)	(1–3 5)	(1 3 5)	—	(2–5)	(1–9)

In the 16 cases, examined as alternative 2, the diameter of the gastroduodenal artery did not alter between series S and series SE On the other hand, the arterial filling phase of the gastroduodenal artery increased from series S to series SE in the mean from 0 9 to 1 3 seconds (Table 1) The number and width of the small pancreatic arteries and the pancreatographic effect were in general equal in the two series both in the head and the tail

Pancreatitis (9 patients) After epinephrine and after secretin and epinephrine combined, the circulation through the pancreas decreased

The diameter of the gastroduodenal artery decreased from series 0 to series SE in 7 of the 9 patients and was equally large in 2 The mean decrease was from 3 5 mm to 3 0 mm The arterial filling phase of the gastroduodenal artery increased from 1 4 to 4 7 seconds (Table 1, Fig. 2)

Compared with series 0, the pancreatographic effect decreased after secretin and epinephrine in 7 of the 9 patients and was unchanged in 2 The pancreatographic effect was unchanged between series E and series SE After secretin alone the pan-

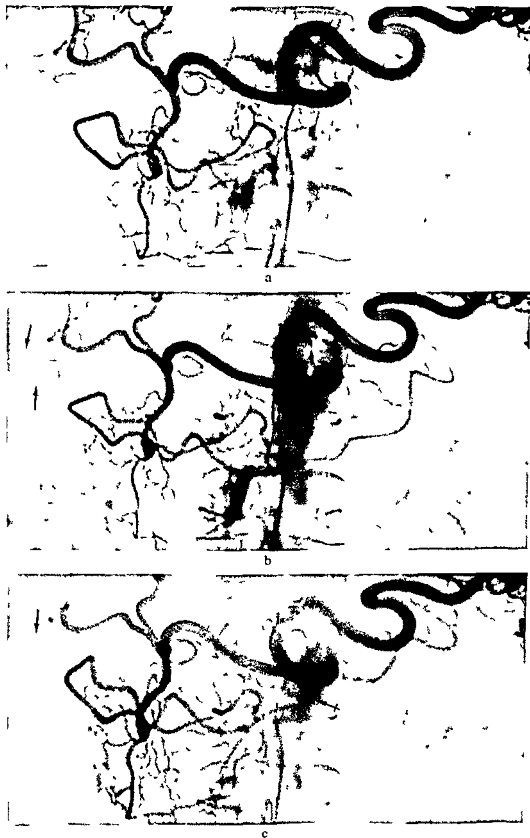


Fig 1 (For legend see opposite page)

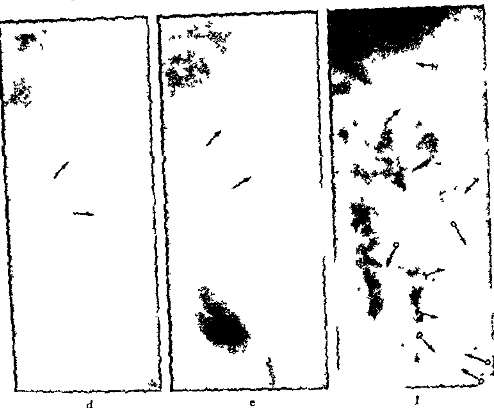


Fig 1 Case 32 Normal celiac angiography perform... second and d) 21 se

maximum contrast... filling of hepatic an... in (d) or (e) In f) sl... of pancreas and du...

creatographic effect increased in all cases as compared with the series without pharmaceuticals

Influence of gastric and mesenteric circulation on the visibility of pancreas

The left and right gastric arteries constricted after epinephrine and also after secretin and epinephrine and consequently there was no distracting contrast filling of the gastric vessels in series E and SE (Fig 4)

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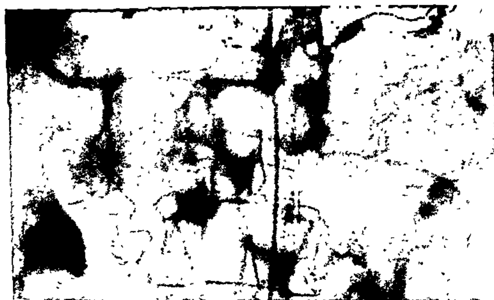
a



b

Fig 2 Case 14 Chronic pancreatitis with acute exacerbation and probably cholangitis Celiac

mon hepatic vein (↔) are tortuous and irregular similar to the appearance of the choledochal duct in cholangitis and pancreatitis Pancreaticoduodenal (↦) splenic and portal veins normal



c

d

Fig. 2. (For legend see opposite page.)

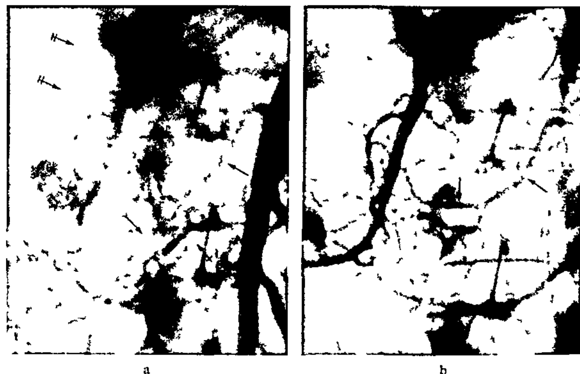


Fig 3 Case 37 Normal except for choledocholithiasis combined celiac and superior mesenteric angiography without pharmaceuticals 2 seconds after start of contrast medium injection (a) and celiac angiography alone with 90 clinical units of secretin injected into the celiac artery 1 75 minutes before and 6 μg of epinephrine 20 seconds before injection of contrast medium (b) b) 2 5 seconds after start of contrast medium injection With secretin and epinephrine (b) the visibility of the pancreatic arteries improved partly because the gastroduodenal artery and the pancreaticoduodenal arteries widened and partly because distracting contrast filling of the middle colic artery (↔) and the right gastric artery (⇸) seen in (a) have disappeared In that part of the head of pancreas normally supplied by the sup mesenteric artery the arteries (→) are widened and have higher contrasting effect in film (b) than in film (a) in spite of celiac angiography alone in (b)

and spleen and directed to the pancreas As a consequence a retrograde contrast filling was obtained of small pancreatic branches of the superior mesenteric artery and in about half of the cases retrograde contrast filling reached the main trunk of the superior mesenteric artery (Figs 1, 3, 4) In 2 cases a combined celiac and superior mesenteric angiography without pharmaceuticals was performed for a comparison with celiacography with secretin and epinephrine In these 2 cases the visibility of the pancreatic arteries improved in series SE, partly because the contrasting effect of the pancreatic arteries increased, and partly because distracting contrast filling of the gastric, jejunal and colic arteries disappeared (Fig 3)

Splenic circulation

The splenic circulation decreased after secretin and epinephrine in all but 3 cases In these 3 patients no effect of epinephrine could be detected either in series E or in series SE probably because the tip of the catheter was directed towards the common

hepatic artery so that no epinephrine reached the splenic artery (Fig 1) The arterial filling phase of the splenic artery increased from series 0 to series SE in the mean from 1 1 to 8 0 seconds and the arterial phase from 4 1 to 17 1 seconds

In 7 normal cases examined as alternative 3, the arterial filling phase decreased between series E and series SE in the mean from 8 9 to 6 1 seconds and the arterial phase from 22 6 to 13 4 seconds The number and width of the arteries in the tail as well as the pancreatographic effect increased when secretin was added, i e from series E to series SE which could explain the shortening of the arterial filling phase and the arterial phase of the splenic artery in series SE compared with series E

Hepatic circulation

No difference was recorded between series E and series SE in the hepatic circulation In the normal liver the circulation decreased both after epinephrine and after secretin and epinephrine the arterial filling phase and the arterial phase increased and the diameter of the peripheral arteries diminished In 8 out of 12 patients with metastases in the liver the pharmaceuticals yielded diagnostic advantages (Figs 4, 7) The normal arteries constricted and as a consequence the contrast medium was directed to less reactive abnormal areas and the contrast medium accumulation became more intense in the metastases There was no apparent difference between series E and series SE in the cases performed according to alternative 3

The veins

The splenic and portal veins In series E and series SE the contrasting effect of the portal vein and the splenic vein was impaired compared with series 0 and particularly when compared with series S (Fig 5)

The maximum contrasting effect of the portal vein was always of a lesser degree and occurred in the mean 10 seconds later in series SE than in series 0 In series S the portal and the splenic veins were earlier contrast filled with a higher contrasting effect compared with series 0 The diagnostic possibilities thus increased after secretin in agreement with previous investigations (UDÉN 1969)

The small veins It has been possible to identify the choledochal (Figs 1, 2, 4, 5), the common hepatic (Figs 1, 2, 5) and the pancreaticoduodenal (Figs 1, 2) veins As a parameter for these small veins in the analyses of the circulation, the choledochal vein was chosen In series SE the choledochal vein could be identified in 27 of the 39 patients In series 0 the choledochal vein was identified in 9 cases and the contrasting effect of the vein was always low, of degree 1 in 7 cases and of degree 2 in 2 cases The contrasting effect of the vein increased after secretin and epinephrine averaging 2 degrees (Figs 1, 5), except in 4 patients with [illegible]

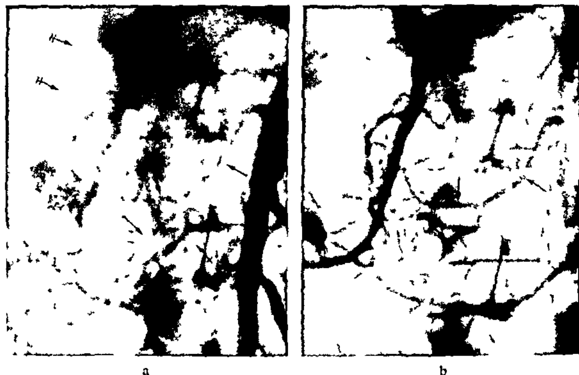
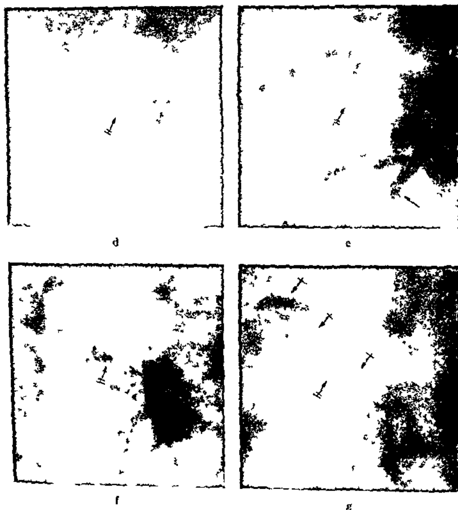


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Splenic circulation

The splenic circulation decreased after secretin and epinephrine in all but 3 cases In these 3 patients no effect of epinephrine could be detected either in series E or in series SE probably because the tip of the catheter was directed towards the common



d e f g

Fig. 4 Case 24 Carcinoma of head of pancreas with l... ing to alternative 3
SE b) 1 5 seconds



a



b



c

F g 4 (For legend see opposite page)

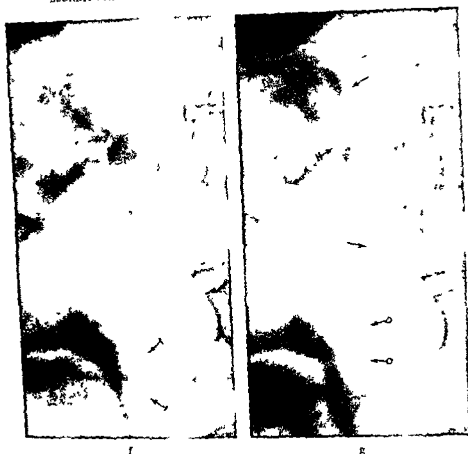


Fig 5 Case 4 ...

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of the early filling In series S the choledochal vein was identified in 13 of the 23 patients and the contrasting effect of the vein was nearly always of the same degree as in series SE and in some cases more intense (Fig 5)

In 10 patients the choledochal vein could not be identified in any series Of these, one had pancreatitis, 2 had tumours in the head of the pancreas (Figs 6, 7), 2 had



Fig 5 (For legend see opposite page)

In series SE the first appearance of contrast medium in the choledochal vein and often the maximum contrasting effect of the vein occurred during the arterial phase of the liver and the stomach—epinephrine effect (Fig 1) In the beginning, before knowing how to recognize it, this vein was considered as an abnormal vein because



Fig 7 (For legend see opposite page)



Fig 6 Case 1 Carcinoma of head of pancreas without metastases in the liver Percutaneous transhepatic cholangiography Total obstruction of the choledochal duct at the papilla

metastases in the vicinity of the head (one from a primary carcinoma of the liver and one from a carcinoma of the colon), one had a gastric carcinoma with carcinomatosis of the peritoneum, one had cirrhosis of the liver and 3 were normal

Seven patients with pancreatitis were examined as alternative 2 The contrasting effect of the choledochal vein decreased in 6 cases from series S to series SE, caused by the decreased pancreatic circulation after epinephrine in pancreatitis (Fig 2) In one patient with pancreatitis and probably cholangitis the choledochal vein was deformed as the choledochal duct may be in pancreatitis (MARIONS 1974) and cholangitis (Fig 2)

The choledochal vein became filled with contrast medium in 6 of 8 patients with malignancy of the pancreas and it was normal in the patient with a benign Schwannoma in the descending part of the duodenum

Fig 7 Same case as in Fig 6 Celiac angiography according to alternative 2 Series 0 b) exposed

in one, moderate in 4 and prominent in 2 (Figs 4, 5) With secretin this effect occurred in 4 of 6 patients, and with epinephrine in one patient only

Abnormal veins could be recorded in every case after secretin and epinephrine (Figs 4, 5, 7) The contrasting effect of the abnormal veins was high in 5, moderate in one and low in 2 Without any pharmaceuticals abnormal veins were noticed in 3 cases and the contrasting effect of the veins was always low (Figs 4, 7) With secretin abnormal veins could be recorded in 5 of the 6 patients (Fig 7) and with epinephrine alone in the remaining patient (Fig 4)

The choledochal vein became filled in series SE in 6 of the 8 patients In 4 of them the vein was clearly widened, probably squeezed by the tumour (Fig 5) The contrasting effect of the vein was high in one and moderate in 3 In 2 cases the choledochal vein could not be identified, probably being completely obstructed by the tumour *In these 2 cases numerous abnormal veins existed in the region of the head of the* pancreas and in the descending duodenum The tumours were drained through gastric veins (Fig 7, Table 2) In the 2 remaining cases of carcinoma the choledochal vein was normal (Fig 4)

In series 0 the choledochal vein was slightly filled in 2 of the 8 cases The 2 cases were 2 of 4 with widened and distally squeezed choledochal veins The contrasting effect of these 2 was low in series 0 compared with series SE (Fig 5)

Discussion

Pancreas It was found that epinephrine causes a constriction *of pancreatic arteries* in pancreatitis, but not with the carcinomas nor in normal pancreas This observation is in agreement with BOIJSEN & REDMAN (1967) The same constriction was obtained when epinephrine was combined with secretin TYLÉN & ARNESJÖ (1973) declared that the constriction is not constant and reported constriction in only 6 of 20 cases On the other hand, they used various vasoconstricting substances such as epinephrine, nor-epinephrine and vasopressin *In intestinal* angiography epinephrine produces a *vasoconstriction of the arteries* supplying inflammatory lesions as in Crohn s disease, ulcerative colitis, ischemic colitis and diverticulitis (UDÉN 1973, *HOLMSTRÖM et coll 1974)* In carcinoma of the colon KAHN et coll (1967) observed constriction, after epinephrine, of the arteries supplying the tumour in about half of their cases and called it the 'false epinephrine test' A carcinoma of the colon is often ulcerated and infected by E. coli with a marked inflammation in the surroundings The cause of the 'false epinephrine test' is probably the inflammation Normally no vasoconstriction is produced by epinephrine on the cystic artery (Fig 1), but KAUDE & WIRTANEN (1970) recorded *vasoconstriction in 11 of their 42 cases, probably caused* in these cases by an inflammatory lesion *of the gallbladder* Epinephrine thus produces vasoconstriction in inflammatory lesions The normal balance between alfa- and beta-

Table 2

Influence of secretin and epinephrine on the angiographic signs of malignancy of pancreas

Case No	Displacement of arteries	Stenosed arteries	Abnormal arteries		Contrasting effect of tumour		Abnormal veins		Choledochal vein	
			0	SE	0	SE	0	SE	0	SE
1	0	0	1	1	0	2	0	3	0	0
2	0	0	2	3	0	2	0	1	0	2*
3	3	1	2	2	1	2	1	3	0	0
4	0	1	0	0	0	2	1	3	1	2*
5	1	0	1	1	0	1	0	2	1	3*
6	2	0	0	0	0	0	0	1	0	1
24	0	0	1	1	1	3	0	3	0	1
33	2	2	1	3	0	3	1	3	0	2*

* choledochal vein dilated

0 = no, 1 = slight, 2 = moderate, 3 = prominent contrasting effect
series 0 = without pharmaceuticals, series SE = with secretin and epinephrine combined

Influence of secretin and epinephrine on the angiographic appearances of carcinoma of the pancreas

In the material, 6 patients had carcinoma in the head of the pancreas and 2 metastases in the head, one from a uterine carcinoma and one from a bronchial carcinoma Of these patients, 6 were examined according to alternative 2, one to alternative 3 and one to alternative 1 only (Table 2)

Displacement of vessels was prominent in one case, moderate in 2 and slight in one case, in the other 5 no displacement could be registered

Irregular stenoses or encasement of the arteries were recorded in 3 cases, slight in one and moderate in 2 In the other 5 no stenoses could be detected

Abnormal arteries were filled in 6 of 8 tumour cases The contrasting effect of the abnormal arteries increased after secretin and epinephrine in 2 and consequently the abnormal arteries became more easily recognized in these cases (Fig 4)

The contrasting effect of the tumour increased after secretin and epinephrine Without pharmaceuticals a slight contrasting effect occurred in only 2 cases After secretin and epinephrine this effect was recorded in 7 of the 8 cases, of slight degree

UDÉN (1969) in selected cases A carcinoma of the pancreas cannot be supposed to act as an effect organ for secretin because the carcinoma does not produce bicarbonate and water on secretin stimulation, as the normal pancreas does If the abnormal arteries, capillaries and veins were newly formed vessels in a carcinoma of pancreas, they would not react to secretin with widening and increased blood flow rate, i e. earlier filling and higher contrasting effect The fact that these effects do occur after secretin, supports the opinion of MARIONS that the abnormal vessels are pre-existing vessels, some widened and some stenosed or obstructed, because a greater amount of blood has to pass through the widened vessels after secretin to the normal part of pancreas and duodenum For the same reason a contrasting effect of the tumour cannot be increased after secretin by newly formed tumour capillaries but only by widened pre-existing capillaries

LUNDERQUIST (1965) never noticed any abnormal veins in his material of 36 carcinomas of the pancreas The present results suggest that abnormal veins are a better diagnostic sign of carcinoma than the four classical signs (1) displacement of arteries may be caused by carcinoma but also by cysts, pseudocysts and abscesses in the pancreas, (2) stenosed arteries may be caused by carcinoma but also by pancreatitis and arteriosclerosis, (3) abnormal arteries are often difficult to differentiate from small pancreatic arteries deformed by inflammatory lesions (Fig 2), and (4) increased contrasting effect of the tumour occurs only in about 20 per cent of carcinoma without pharmaceuticals After secretin and after secretin and epinephrine, this contrasting effect of the tumour increases and it becomes a more valuable sign of carcinoma This effect was obtained without pharmaceuticals in 2 of 8 cases and with secretin and epinephrine in 7 of them (Table 2, Figs 4, 5)

If filling of the veins in the region of the descending duodenum and the head of the pancreas is obtained, the normal veins such as the choledochal vein and the pancreaticoduodenal vein have to be identified If these cannot be identified but only other small veins (Fig. 7) an obstruction of these veins, probably caused by a carcinoma in the head of the pancreas must be considered

Conclusion

The use of secretin and epinephrine has proven to be valuable for enhancing angiography of the pancreas It results in an improved demonstration of the normal and abnormal vascularity with a consequent increase in diagnostic information The following basic observations were made

(1) With secretin and epinephrine combined and often with secretin alone small veins such as the choledochal, the common hepatic and pancreaticoduodenal veins can be demonstrated These veins are very useful in the diagnosis both of carcinoma and pancreatitis If small veins are filled in or around the head of pancreas, the choledochal, the common hepatic and the pancreaticoduodenal veins at least should be identified—otherwise the veins are abnormal

receptors seems to be lost One explanation could be that the threshold of beta-receptors is increased In any case, after epinephrine, there is a decreased blood flow and a constriction of the arteries supplying inflammatory lesions The more intense the inflammation, the more marked the vasoconstriction seems to be (Fig 2)

In carcinoma of the pancreas, however, no vasoconstriction was ever observed after epinephrine, in spite of the slight inflammatory reaction almost invariably present around a carcinoma of the pancreas (MARIONS 1964) or the more marked inflammation (GLEEN & THORBJARNSON 1964, KLINTRUP 1966) secondary to tumour invasion This type of inflammation does not seem to cause any disturbance of the alpha- and beta-receptors

Spleen In the 7 normal examinations performed according to alternative 3 the arterial filling phase and the arterial phase was shortened in the spleen from series E to series SE The explanation could be that the circulation through the tail and the body of the pancreas increased, when secretin was added and in this way the contrast medium was diverted from the spleen

In 3 cases no effect of epinephrine could be detected in the spleen either with epinephrine alone or with secretin and epinephrine (Fig 1), probably due to the position of the catheter such that no epinephrine reached the splenic artery To ensure the same distribution of the pharmaceuticals as the contrast medium the administration of pharmaceuticals has to be performed in the same way as that of the contrast medium, which means with large volume and under high pressure This is important, if any conclusions are to be drawn from the effect of the vasoconstrictive substances

The choledochal vein The blood flow in the pancreas increases after secretin, and after secretin and epinephrine particularly in the head of the pancreas and duodenum Contrast filling is therefore obtained of small veins in this region, namely the choledochal vein, the common hepatic vein and the pancreaticoduodenal vein These small veins are valuable in diagnosis because both inflammatory and neoplastic lesions deform the veins earlier than the arteries because of the softer and thinner walls These veins could be deformed in pancreatitis and cholangitis (Fig 2), squeezed and widened by tumours (Fig 5) or totally obstructed (Fig 7, Table 2)

Angiographic appearances of malignancy in the pancreas Veins are affected earlier than arteries by a tumour since they have softer and thinner walls and are therefore stenosed or obstructed earlier than arteries This stensosis of veins gives rise to collaterals, i e widening of other pre-existing veins (MARIONS 1974) In the present material, abnormal veins were always recorded in malignancy of the pancreas after secretin and epinephrine and after secretin alone in all but one Without pharmaceuticals abnormal veins could be seen in only 3 cases and the contrasting effect was always low This filling of abnormal veins after secretin has been reported by

RÉSUMÉ

L'auteur a fait à 39 malades une angiographie coeliaque sans agents pharmacodynamiques, avec épinéphrine (adrénaline) ou secrétine seule ou avec adrénaline et secrétine associées La secrétine et en particulier l association d adrénaline et de secretine augmentent la visibilite des artères pancréatiques, des capillaires et des veines, et entrainent par conséquent une amélioration de l information Des petites veines normales comme la veine choledocienne et les veines pancreatico-duodénales ont un grand interet diagnostique Avec l association d adrénaline et de secrétine des veines anormales et presque toujours des capillaires anormaux se sont remplis de moyen de contraste dans les tumeurs malignes du pancreas

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(2) Secretin and epinephrine cause a more intense contrasting effect of abnormal veins and capillaries because a larger amount of contrast medium reaches the pancreas Abnormal veins became filled in every case of pancreatic malignancy and consequently the demonstration of abnormal veins is a better sign of carcinoma than the four classical signs of displacement of vessels, stenosis of arteries, abnormal arteries and increased contrasting effect of the tumour.

(3) A complete pancreatic angiography can be obtained by celiac angiography only, since retrograde contrast filling is obtained of those vessels which ordinarily are supplied by the superior mesenteric artery If a carcinoma is found, an additional injection into the superior mesenteric artery is advisable, in order to assess operability

(4) Distracting contrast filling of gastric, jejunal and colic arteries is avoided

The well-known improvement of the diagnosis of liver malignancy after epinephrine is maintained with secretin and epinephrine combined The less well known constriction of pancreatic arteries caused by epinephrine in pancreatitis is also maintained with secretin and epinephrine combined It appears that the optimum technique for pancreatic angiography includes one series with secretin in order to get a sufficient filling of the tail of pancreas and the splenic and portal veins and one series with secretin and epinephrine combined

Catheterization of the celiac artery is sufficient and thus the examination can be made in a shorter time

SUMMARY

Celiac angiography was performed in 39 patients without pharmaceuticals, with epinephrine or secretin alone and with secretin and epinephrine combined With secretin, and especially with secretin together with epinephrine the visibility of pancreatic arteries, capillaries and veins increased with a consequent improvement in information Normal small veins such as the choledochal and the pancreaticoduodenal veins have proved to be of great diagnostic value With secretin and epinephrine combined abnormal veins and nearly always abnormal capillaries became contrast filled in malignancy of the pancreas

ZUSAMMENFASSUNG

In 39 Patienten wurde eine Angiographie der Arteria coeliaca ohne Pharmaka, mit entweder Epinephrin oder Sekretin oder mit Epinephrin und Sekretin kombiniert, vorgenommen *Mit Sekretin, und besonders mit Sekretin kombiniert mit Epinephrin wurde* die Fullung der Arterien, Kapillaren und Venen des Pankreas verbessert, was eine verbesserte Information zur Folge hatte Normale kleine Venen, wie die Vene des Ductus choledochus und die Venae pancreaticoduodenales, sind von grosser diagnostischer Bedeutung Mit Sekretin und Epinephrin kombiniert wurden pathologische Venen und fast immer pathologische Kapillaren bei Malignitat des Pankreas mit Kontrast gefullt

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HEPATOGRAPHY WITH INTRAVENOUSLY INJECTED EMULSIFIED IODOLIPIDS

Preliminary results

A PINET, V TRAN MINH, M BOUCHERAT, A DUBREUIL and J P MAGIS

The introduction of hepatography with emulsified iodolipids marked a decisive step forward in the examination of the liver Its originality lies in the fact that it provides a homogeneous uptake of the contrast medium in the entire liver which lasts for several hours and thus makes an accurate tomography possible Since 1971, emulsified iodized lipids have been administered by selective arterial approach (LAVAL-JEANTET et coll 1972, LAVAL-JEANTET et coll 1973) either into the celiac or the superior mesenteric artery, hepatography being a complement to conventional angiography Intravenous injection has been tried at the Hopital Edouard Herriot and the preliminary results will now be reported

Material and Methods

Using a batch of AG 60 99, a stable emulsion of iodized lipids supplied by the Guerbet Laboratories, 32 intravenous examinations were performed in 23 men and 8 women of ages ranging from 17 to 77 years, one case underwent 2 hepatographies with a 3 month interval

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Fig 3



Fig 4

Fig 3 Metastases (carcinoma of left colon) Tomography at 13 cm Voluminous defects in the upper and lower areas of right lobe (—►) Supra hepatic vein visible (↔)

Fig 4 Metastases Carcinoma 5 years before Tomography at 13 cm Numerous lesions Two lesions side by side (—►) at lower edge of liver The smallest has a diameter of 0 8 cm

after an injection of diazepam The most frequent side effect was fever which developed after about 6 hours and lasted for short periods of about 3 hours Shivers did not always accompany this rise in temperature, but occurred as a tremor which abated within a few minutes after an injection of diazepam

The present experiences suggest that the tolerance is related to two factors (a) The amount of emulsion used The reactions are marked and constant above 1 2 ml/kg and minimal under this dose However, the amount of AG 60 99 should be adapted to the subject s weight, up to a certain point The maximum dose, which should not be exceeded whatever the subject's weight, seems to be 90 ml This dose is in fact related to the liver mass and not to the body weight (b) The rate of infusion during the first hour This rate is most important Side effects occurring during infusion have almost completely disappeared, using a slow infusion A rate of 30 ml during the first hour, and of 50 to 70 ml during the second hour seems to be optimum

The tolerance to the medium has no relationship to the patient's age It was satisfactory in the oldest patients, thus making it possible to extend the indications of hepatography beyond those of angiography

Results

Quality of the hepatography The uptake of the iodized lipids was satisfactory in all cases It was only partly dependent upon the amount of emulsion excellent results were obtained with doses of 1 0 to 1 5 ml/kg body weight However, the dura-



Fig 1



Fig 2

Fig 1 Normal liver Tomography performed 11 cm from the back, through the inferior vena cava (→) Right large supra hepatic vein (↔) Section of a branch of the portal vein (↔)

Fig 2 Normal liver Tomography performed 13 cm from the back through the hepatic hilum Portal vein with branches (→) and right supra hepatic vein (↔)

Based on experiences with arterial administrations, subjects with decompensated cirrhosis and portal hypertension or with possible primary tumor of the liver were excluded The abnormal portal blood flow or the intra-hepatic shunts existing in these two lesions involve poor uptake of the contrast medium in the liver

Technique The iodized emulsion AG 60 99 was administered by slow infusion (4 hours) in the following doses 2 2 ml/kg in 1 case, 1 5 ml/kg in 1 case, 1 2 ml/kg in 21 cases, and 1 ml/kg in 9 cases, completed to 500 ml with isotonic glucose solution 0 5 %

The infusion flow was constant for 4 hours in the first three cases In the later cases, it was modified as follows 30 ml during the first hour, 70 ml during the second hour, and 200 ml per hour during the next two hours Intramuscular Diazepam and 8 mg of dexamethasone phosphate were given routinely in all cases except the first one

Hypocycloid tomography of the liver in a p and lateral projections was performed immediately after completion of the infusion

Side effects In 8 patients no reaction at all occurred, they included the youngest (17 years) and the three oldest patients (74, 76, 77 years) Various side reactions were encountered in 24 patients temperature increase during the first 24 hours in 20 cases, shivers in 7, nausea or vomiting in 4, and anorexia on the following days in 11 cases

No drop in blood pressure was recorded apart from what is usually observed


Fig 7


Fig 8

Fig 7 *Same patient as in Fig 6* Tomography at 13 cm Metastasis in upper part of right lobe, diam 1 5 cm (→)

Fig. 8 Multiple hydatid cysts Tomography at 9 cm one posterior hydatid cyst of right lobe (→). *Another cyst in hepatic dome*

formed without any *metastases being found* One case with a tumor of the colon was *uncertain A whitish* induration of the inferior surface of the liver was considered *metastatic during the operation* However, the hepatography was negative and a biopsy *revealed a fibrous tissue* possibly originating in Glisson s capsule Only eight months have *elapsed* since the operation and it is too early to judge the final *outcome*

In 4 of 7 cases examined for possible hydatid cyst hepatography revealed the presence *of cysts –multiple* in two cases, single and voluminous in two others Surgery was *carried out in three cases* and confirmed the site of the cysts demon strated by hepatography *The fourth* cyst, which was calcified and single, was not operated upon

In one case a large abscess of the right lobe was revealed Its amebic nature was confirmed by regression on specific medical *treatment*

Two patients had a *hypovascularized* mass at angiography and underwent a complementary venous *hepatography* The first case had a large mass in the left hypochondrium A puncture biopsy *suggested* a hepatic malignancy Angiography demonstrated a cirrhotic *right lobe* and a poorly vascularized left hepatic mass without any new formed *vessels of malignant* appearance At the venous hepatography performed three days *later a homogeneous* uptake of this mass was demon strated which indicated—based on previous experience of a similar lesion, examined

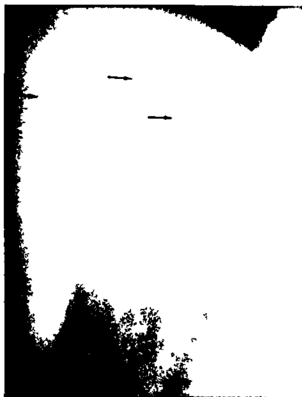


Fig 5



Fig 6

Fig 5 Metastases Carcinoid of appendix two years before Negative scintigraphy Tomography at 7 cm Three lesions visible (→) in upper part of right lobe

Fig 6 Metastases Gastric neoplasm Preoperative hepatography Tomography at 9 cm multiple lesions in right lobe

tion of the uptake depended on the dose if more than 1 5 ml/kg was used, it persisted for more than 24 hours, gradually decreasing Lower doses, approximately 1 2 ml/kg, are to be preferred, as they are better tolerated and still allow a satisfactory tomography to be carried out

A comparison of 32 venous with 48 arterial hepatographies, showed that the venous approach is just as satisfactory as the arterial one

A detailed knowledge of the anatomy of the vascularity and of the biliary ducts is mandatory for an analysis of the different tomographic sections It is necessary to use a tomograph with a hypocycloid movement, to avoid spurious contours caused by the spine disturbing the image

Metastases in the liver were demonstrated in 12 cases of 22 examinations carried out on clinical suggestion of metastases of a known tumor In 11 cases the findings were confirmed by surgery In one case, the metastases were not palpated at operation, as they were located in the center of the liver and very small on the hepatography, but the course of the disease confirmed the diagnosis

The 10 livers which did not display metastases were controlled by palpation at surgery One of the livers was removed post mortem and serial sections were per-

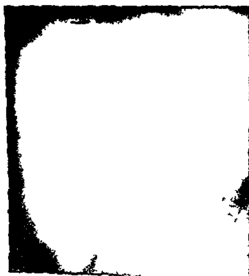


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Fig 9



Fig 10

Fig 9 Same patient as in Fig 8 Tomography at 16 cm a third cyst in inferior part of left lobe (→)

Fig 10 Multiple hydatid cysts of the liver Tomography at 16 cm Three hydatid cysts side by side involving the entire left lobe (→)

by arterial approach—regeneration of the left lobe in a cirrhotic liver This was confirmed by surgery and a repeat biopsy

The second patient was a woman aged 40 without any impairment of her general condition, who had an enlarged liver with disseminated calcic deposits in the right lobe, non-vascularized at angiography Venous hepatography showed a large, irregular polylobar defect in the liver Primarily, malignancy was not suggested, *but later a malignant cholangioma was revealed*

In summary, the presence or absence of a circumscribed lesion of the liver was *confirmed in 31 of 32 cases The smallest lesion detected had a diameter of 0 5 cm* Scintigraphy of the liver was performed in 11 cases of the series, and failed to demonstrate the lesion in 7 cases The nature of the lesion could be assessed in all cases except one (the malignant cholangioma) The present results suggest that metastases appear as more or less rounded and regular defects, and hydatid cysts as *entirely* regular defects with a border of higher uptake The abscess was irregular and surrounded by a region of high uptake

Discussion

This experience, added to that of 48 arterial hepatographies, calls for some comments concerning the position of venous hepatography with regard to angiography and arterial hepatography, and the indications and contraindications of venous hepatography

Venous hepatography has the advantage over arterial hepatography of not being limited by the patient's age Patients over 70 also tolerated the examination well However, venous hepatography should not become a routine examination, the indications should be strictly established in order to obtain a maximum of information and a minimum of failures

The present experiences suggest similar contraindications as for the arterial hepatography decompensated cirrhosis with portal hypertension, and possible primary tumor of the liver and hepatoma in a cirrhotic liver

In such cases an angiography has to be carried out first to demonstrate whether abnormal vascularity exists If this is not the case, the angiography may be followed by injection of the iodized lipids using the same catheter as a supplementary examination

The essential indications for venous hepatography seem to be clinical suggestions of metastases, of cysts (hydatid in particular), or of liver abscesses A non decompensated hepatic cirrhosis is no absolute contraindication to venous hepatography

Many metastases, especially those of neoplasms of the digestive tract, are avascular and thus difficult to diagnose by angiography, as a lesion must be rather large to be detected only on the basis of vascular displacements The left lobe is particularly difficult to examine both by angiography and by scintigraphy Only superficial metastases on the anterior surface of the liver exceeding a diameter of 2 to 3 centimeters are possible to detect with ultrasound Also at laparoscopy, only superficial lesions on the anterior surface and at the lower border of the liver are visible

The possibility of demonstrating a lesion with a diameter less than one centimeter in any part of the liver makes hepatography, combined with tomography, the most accurate and the most reliable method for the detection of metastases It should be included in the routine pre treatment examination of any patient with a visceral malignancy and also during follow up By tomography, an exact localization of a lesion and an estimation of the thickness of the surrounding parenchyma is possible, which is of importance for the surgical approach, particularly in cysts

SUMMARY

Hepatography by slow intravenous infusion of AG 60 99 Guerbet (iodized lipids in a stable emulsion) was performed in 31 patients aged 17 to 77 years, to detect circumscribed hepatic lesions metastases cysts and hepatic abscesses The tolerance was good with minor side effects unrelated to the patient's age The uptake of the medium involves the entire liver and lasts for several hours, allowing tomography to be carried out Intrahepatic lesions with a diameter of less than one centimeter may be demonstrated Hepatography proves to be the most accurate method available at present for exploration of the liver



Fig 9



Fig 10

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HEPATOSPLENOGRAPHY BY INTRAVENOUS INJECTION OF A NEW IODIZED OILY EMULSION

M LAVAL-JEANTET, J L LAMARQUE, P. DREUX, A M. LAVAL-JEANTET and J LAUNAY

Ever since the first experiments by KEITH & BRIGGS (1930), many efforts have been made to perform hepatosplenography (BOCCADORO et coll 1967, CAUSSE 1970, LEDOUX-LEBARD 1939, TEPLICK et coll 1964, ZIMMON & HADGRAFT 1965) The capillary phase of angiography has too short a duration to permit satisfactory tomography to be carried out, which appears to be the only method of detecting small avascular lesions, especially when they are located in the left lobe of the liver. Previously, the uptake of particulate substances by the reticulo-endothelial tissue has been tried Thorotrast (thorium dioxide) was used with satisfactory radiographic results in both animal experiments and in man, but had to be abandoned as a consequence of its radiation effects causing cirrhosis of the liver and even malignancies later on Oral hepatosplenography was reported by OLSSON & EKMAN (1949) They used halogenated fatty acids and in animal experiments obtained radiographically satisfactory uptake in the liver, spleen and several fatty tissues However, these experiments do not seem to have been continued Until recently [illegible]

[illegible] ... GUTRBIT 1964, MASY 1950, OLSSON 1947)

Submitted for publication 12 December 1974

ZUSAMMENFASSUNG

Eine Hepatographie durch langsame intravenöse Infusion von AG 60 99 Guebert (jodierte Lipide in einer stabilen Emulsion) wurde bei 31 Patienten im Alter von 17 bis 77 Jahren vorgenommen um umschriebene Läsionen der Leber festzustellen Metastasen, Zysten und Leberabszesse Die Verträglichkeit war gut mit geringen Nebeneffekten, die vom Alter der Patienten unabhängig waren Die Aufnahme des Mittels betraf die gesamte Leber und hielt einige Stunden an, was eine Tomographie durchzufuhren ermoglichte Intrahepatische Läsionen mit einem Diameter von weniger als ein Zentimeter konnen nachgewiesen werden Die Hepatographie scheint gegenwärtig die zuverlassigste Methode zur Leberuntersuchung zu sein

RÉSUMÉ

Trente-deux hépatographies par perfusion veineuse lente d'AG 60 99 Guerbet (lipides iodés en émulsion stable) ont été réalisées chez 31 patients âgés de 17 à 77 ans, à la recherche de processus expansifs localisés du foie métastases, kystes et abcès hépatiques La tolérance de l émulsion a été bonne avec des effets secondaires minimes, indépendants de l'âge L'opacification intéresse la totalité du foie et persiste plusieurs heures, permettant des tomographies en série Des lésions intrahépatiques d'un diamètre inférieur à un centimetre ont été détectées L'hépatographie apparait comme la méthode actuelle la plus precise et la plus fiable pour l'exploration du foie

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Fig. 2 Normal hepatography Section III The vertical filling defect along the spine caused by the inferior vena cava (+→), the small round defect by a portal vein (→) Diagnostic errors are mainly due to defects caused by hepatic vessels

less traumatic method which did not require the stripping of the umbilical vein or mesenteric artery catheterization was sought This led to the development of intra-venous administration

The development of injectable oily emulsions for parenteral nutrition has given a better understanding of the metabolism of such substances and of the possible side-effects of intra-venous infusion (FREEMAN 1955, JEAN 1966, LARCAN 1966, WRETLIND 1964)

Animal experiments using iodized oily emulsions with small particle sizes demonstrated that there was sufficient tolerance to obtain hepatosplenographies, identical to those obtained by intra-arterial injection, and with doses considerably lower than the threshold of toxicity (WILLEMIN et coll 1975) The experiments will be published elsewhere, here are reported only the first 30 intravenous hepatosplenographies in man, carried out by the Paris and Montpellier groups

Material and Methods

The product used for injection, AG 60 99 (Guerbet), is a stable emulsion of iodized fatty acid esters of poppy seed oil, containing 0 20 mg I/ml, the emulsifying agent is composed of non-ionic tensioactive substances (purified lecithins) AG 60 99 has a milky appearance and is not altered for several weeks by storage The particles have an average diameter of 1 3 microns The LD_{50} administered intravenously to mice is 16 ml kg, i e 3 2 g of iodine per kg, and the LD_0 is 9 ml/kg, i e 1 8 g of iodine per kg Doses used in man range from 0 8 to 1 8 ml/kg, doses of 1 ml or more provide a satisfactory hepatosplenographic effect (Fig 1)



a



b

Fig 1 Normal hepatosplenography Man 32 years old Hodgkin s disease Injection of 1 8 ml/kg of AG 60 99 a) Conventional film Homogeneous parenchymal uptake in liver and spleen b) Tomography of the spleen reveals defects due to vascularity

Less toxic substances were developed in 1965 This brought about a renewed interest in hepatosplenography (DALION et coll 1966, GUERBET 1965) The intention was to develop a method for selective hepatic vascular injection which would reduce the distribution of the oily substances to other organs and thus decrease the risk of pulmonary, renal or cerebral embolism After evaluating transplenic portal hepatography (GUNTZ & CARON 1968 LEGER et coll 1968, PALVOGVI & LACZAY 1970) or umbilical hepatography (GONZALEZ CARBALHAES 1959 LAVOIE et coll 1967), the arterial approach (LAVAL-JEANTET et coll 1972) was preferred A simpler and



Fig 4 Hodgkin s disease Woman 42 years old Large round expanding mass in the spleen



Fig 5



Fig 6

Fig 5 Hodgkin s disease Woman 38 years old Multiple nodular defects in the spleen

Fig. 6 Liver metastases from a rectal carcinoma Man 65 years old Lesions with a diameter of 1 cm are clearly visible

The differentiation between a defect caused by a vein and one by a tumour may be facilitated by comparing the appearances on antero-posterior and lateral films, as well as on tomographic sections anterior and posterior to the defect If it is caused by a vein it may be rounded in one projection, but in another it may branch out on sections adjacent to the one with the round defect In some cases a comparison

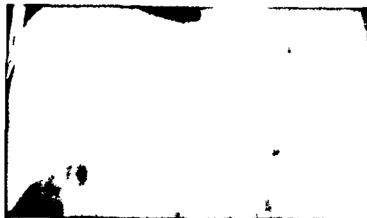


Fig 3 Normal hepatography Section V The left lobe clearly defined

Two injection methods were used, in 12 cases, the undiluted product was infused relatively rapidly (average duration 1 hour), in 18 cases the technique recommended for parenteral nutrition (FREEMAN, JEAN) was applied, i e the AG 60 99 was diluted in glucose serum 1 5 and slowly infused (approximately four hours)

At the end of the infusion one conventional film was exposed, followed by hypo cycloid or linear tomography in antero posterior and often lateral projections as well The hepatosplenographic effect persisted for 24 to 48 hours, then gradually decreased and had disappeared completely after the third day

Results

Physiologic appearances of hepatography with liposoluble substances The hepatographic effect was homogeneous, involving all the hepatic segments Anatomic details not demonstrated with other techniques (angiography, scanning) were revealed, details that should be recognized in order to avoid confusion with pathologic processes

Various extrahepatic structures may be used for facilitating analysis of the normal anatomy and the determination of the site of lesions in the a p view In the present series the following sections were used from the back forwards

Section I Blurring of the posterior part of the ribs
Section II Vertebrae Th11, Th12 and kidneys sharply demonstrated
Section III Blurring of Th11, Th12 (Fig 2)
Section IV Maximum width of the liver
Section V Anterior plane (Fig 3)

Physiologic filling defects appear in the liver, representing structures which have not accumulated contrast medium, such as vessels or bile ducts In the a p view, section III, the inferior vena cava causes a vertical filling defect with parallel edges The two venous systems of the liver, i e the portal and the hepatic, seldom cause linear or rounded filling defects The portal vessels branch out from the hilum, which appears as a notch on the inferior surface of the liver, visible on sections III and IV

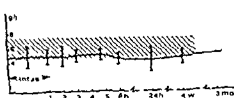


Fig 7

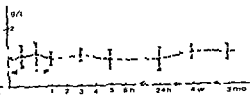


Fig 8

Fig 7 Total lipid content of serum. Slight variations, within normal limits

Fig 8 Variations of serum triglyceride concentrations

Hematologic effects Blood samples were taken in 22 cases In 12 cases, the injection of 0 8 to 1 5 ml of AG 60 99 led to a moderate drop (less than 10 per cent) of the red blood cell count

A transient (one day) leucocytosis was found during the temperature raise the first day, the leucocytic count returning to normal on the second or third day In 8 cases, no change of the leucocytic count occurred

The most significant alteration was a slight decrease in platelet count (10 to 20 per cent) which seems to be related to activation of factor XII and the thrombin generation This may be counteracted rapidly by heparin, but it was not used consistently Because of their antisludge effect, Dextran, or Rheomacrodex was added to the administration of the iodized oil in 22 of 30 infusions

The hematologic abnormalities observed gave no clinical manifestations They were transient and minor, however, they serve to contraindicate hepatosplenography in patients with disorders of coagulation, and especially in those with signs of hypercoagulation

Effects on serum lipid content These effects were examined in 12 cases Blood samples were collected before the injection of the contrast medium, at the end of the injection and the next morning In most cases, additional samples were collected during the infusion and a few hours (1 to 5 hours) after the infusion In two cases, samples were collected at 10 min intervals during the first 60 minutes

The effect on the serum lipid content was analysed by the following methods Determination of (1) total lipid by nephelometry, utilizing a semiautomatic method (GIRARD et coll 1970), (2) total cholesterol (FIET et coll 1971), (3) triglycerides by fluorimetry using the method of Hantzsch (BARTHELEMY 1972, KESSLER & LEDERER 1965 MAC QUEEN et coll 1973) and (4) lipoprotein electrophoresis on cellulose acetate (Cellogel) (MICHAUX et coll 1973)

The reliability of the methods was tested in relation to the drugs administered in connection with hepatography, such as Dextran, Rheomacrodex, diazepam and hydrocortisone The techniques and results of these tests will be reported later

The general results appear in Figs 7 to 9 The times plotted on the abscissa were determined from the end of the infusion

Table 1

Hodgkin's disease Seventeen cases with splenectomy

Splenectomy	Diagnosis before splenectomy			
	Intravenous splenography		Isotope scanning	
	Correct	Error	Correct	Error
Histologic lesions	5	1	3	3
Normal spleen	12	2	9	3

with the venous phase of an angiography is necessary The site of the defect may also facilitate the differentiation In section III a rounded venous defect often appears on the inferior medial aspect of the liver (Fig 2)

Radiographic results Thirty intravenous hepatosplenographies were performed, in 18 patients with Hodgkin's disease (Figs 4, 5), in 12 with possible metastases or other intrahepatic expanding lesions Of the latter, 7 cases were pathologic metastases (5), hydatid cyst (1) and hepatic abscess (1) Surgery or complementary examinations confirmed the findings in 5 cases Hepatography proved superior to isotope scanning in the detection of metastases (Fig 6) Experimentally, LAMARQUE (1974) has demonstrated that the smallest lesion detectable by hepatography has a diameter of less than 1 cm The results of splenography in the cases with Hodgkin's disease appear in the Table The one case erroneously diagnosed as normal had a diffuse miliary spread of nodules a few mm in diameter at microscopy The uptake of the contrast medium appeared homogeneous This case illustrates the limitations of the method However, such miliary spread seems to be unusual In 5 cases, nodular lesions not clinically suggested, were revealed

Side effects Intravenous injection of iodized oily emulsions caused some reaction in about 50 per cent of the cases Fever frequently occurred, 2 to 4 hours after the infusion, the temperature rapidly rising to 38 5 to 39°C, sometimes 40°C, from the eighth to the twelfth hour it gradually decreased and was usually normal by the following morning A feeling of cold associated with shivering was encountered during the injection, 1 to 2 hours after the beginning of the infusion, disappearing rapidly after the administration of diazepam Vomiting, general discomfort, lack of appetite and headache occurred less frequently

Respiratory disturbances with dyspnea occurred in 5 cases with pulmonary abnormalities, namely extensive pulmonary metastasis, recent mediastinal irradiation or lymphography the day before the hepatography

Allergic reactions, rhinorrhea, headache and floods of tears for some hours following the examination, occurred in 3 cases, probably due to iodine hypersensitivity

Discussion

The experience obtained using iodized oily emulsions as contrast medium administered intra arterially or intra portally (over 500 cases), has clearly demonstrated the clinical value of hepatography More accurate than isotope scanning, this method also proved to be superior to angiography for the detection of small intraparenchymatous lesions It is the only method which makes it possible to obtain a satisfactory and safe uptake of a contrast medium for sufficient duration to allow detailed tomography also of the left lobe Due to superimposition, this lobe is difficult to evaluate on angiography (LAVAL JEANTET et coll 1972) The same is true of the spleen Superimposition often disturbs the image, and the use of angiography to detect splenic lesions in Hodgkin's disease has failed (LAVAL-JEANTET & TRISTANT 1971) However, splenography with iodized oily emulsions seems to permit the detection of nodular lesions more accurately than isotope scanning (LAVAL-JEANTET et coll 1973)

Hepatosplenography was decisive in planning surgery It allowed determination of the site of the lesion, the thickness and state of the parenchyma surrounding the lesion, and could reveal lesions of the dome or posterior surface, which could not be detected by laparoscopy

The emulsion used, AG 60 99, is rapidly metabolized and its experimental toxicity is slight ($LD_{50} \approx 16$ ml/kg) The intravenous infusion is easily performed and without risk, since the veins exhibit perfect tolerance to the substance The method fulfils most of the demands of THOMAS (1962) and BERGER, except for the side effects which, however, are transitory and familiar to users of nutritional lipid emulsions, fever shivering and headaches are reported in over 50 per cent of the cases by some authors (FREEMAN) Considerable pharmacologic progress has been made and administration has been improved (ultra slow infusion) (WRETLIND) Further improvement of lipid emulsions and increased tolerance can be expected

The pulmonary uptake remains a problem Arterial injection (LAVAL-JEANTET et coll 1972) was suggested to prevent or to limit the [illegible] which is [illegible] particles [illegible] by the [illegible] per cent in the animal experiments), but the amount decreases rapidly After 12 hours only 5 per cent of the total dose remained The pulmonary retention of particles is probably the cause of the three respiratory incidents encountered in the subjects with impaired respiratory function

Effects on lipid metabolism seem to be slight, hypertriglyceridemia is transient, and even in subjects with disorders of lipid metabolism, the complications were slight and of short duration

The present experience suggests the following contra indications Hepatography should be avoided in subjects with liver insufficiency, especially cirrhosis, as the uptake is slight and the lipid overload not harmless It should also be avoided in subjects



Fig 9

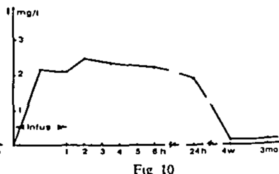


Fig 10

Fig 9 Variations of serum cholesterol concentrations

Fig 10 Protein bound iodine Following an immediate considerable rise in the serum iodine content, the high level is maintained for 24 hours, but returns to a normal value within 4 weeks

No abnormality was caused by the infusion of AG 60 99, regardless of whether the examination was performed in subjects with a normal (4 cases) initial lipid balance, or with a disturbed one (6 cases) The variations of the different lipid parameters were always slight and remained within normal limits The following values were considered to be normal total lipid 4 5 to 7 5 g/l, total cholesterol 1 6 to 2 4 g/l triglycerides 0 5 to 1 5 g/l and lipoproteinography, pre $\alpha + \alpha$ lipoproteins 20 to 25 per cent, pre β lipoproteins 60 to 75 per cent, chylomicrons none

The concentrations of the contrast medium and of the triglycerides in the blood were measured There was no overload Activation of lipase lipoprotein may explain the decrease of the induced hyperlipemia when triglycerides and total lipid content are determined 4 to 6 hours after the end of the infusion

The fatty acids released during hydrolysis are metabolized or stored The total cholesterol value decreased only slightly which is in accordance with observations made in nutritional lipid infusions, similar observations were also made in the course of animal experiments of hepatography There seems to be little risk of blocking function

Effects on iodine content in serum Only the protein bound iodine was determined, by the method of Dreux Under normal conditions the method gives information of the hormone bound iodine Following hepatography, an increase was observed, which could mean that the iodine added by AG 60 99 had become bound to the proteins of the thyroid hormones either as iodized fatty acids or as iodides There was a remarkable conformity between the values obtained, probably explained by the limited capacity of proteins to bind iodized molecules

The quantity of injected iodine was about 26 mg and the maximum amount of protein bound iodine 7 5 mg (2 51 in the plasma)

Renal elimination of the iodide was rapid (30 per cent within 24 hours) and the contrast medium could be seen in the bladder on films exposed on the following day Normal values were found 4 weeks and 3 months after the hepatosplenography (Fig 10) A more detailed analysis of the iodine elimination is in progress

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with coagulopathies or a history of cardiac or cerebrovascular lesions, respiratory insufficiency, recent lymphography and extensive pulmonary lesions should also be regarded as contra indications

SUMMARY

Hepatosplenography with intravenously injected iodized lipid emulsion has been performed in 30 cases and the results reported The side effects were minor and transient as the elimination is rapid The uptake in the liver was satisfactory and permitted tomography both of the liver and the spleen Small neoplasms and splenic nodules in Hodgkin's disease could be detected and located accurately

ZUSAMMENFASSUNG

Hepatosplenographie mit intravenos injizierter jodizierter Lipid Emulsion wurde in 30 Fallen vorgenommen und die Ergebnisse werden beschrieben Die Nebeneffekte waren gering und vorubergehend, da die Elimination rasch ist Die Aufnahme in der Leber war zufriedenstellend und ermöglichte Tomographie von sowohl Leber als Milz Kleine Neoplasmen in der Leber und noduläre Milzveranderungen bei der Sternberg'schen Erkrankung konnten entdeckt und genau lokalisiert werden

RÉSUMÉ

Les auteurs présentent les résultats de 30 hépato splénographies par injection intra veineuse d'émulsion de lipides iodés Les effets secondaires ont éte minimes et transitoires, car l élimination est rapide La fixation dans le foie a été satisfaisante et a permis la tomographie du foie et de la rate Cette méthode a permis de mettre en évidence et de localiser exactement des petites tumeurs et des nodules spléniques dans la maladie de Hodgkin

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HEMANGIOMA OF THE LIVER

Report of two cases

J TH JENSEN and T KLINGE

Angiography in hemangioma of the liver has been reported several times in the last few years The use of angiography both in establishing the primary diagnosis and in a follow-up examination has, however, been reported only once before (TAVERNIER et coll 1972) after intervening surgery In the two cases presented in this report a follow-up examination was carried out after steroid treatment in one patient, and after 6 years without treatment in the other case

Hemangiomas are thought to be embryonic sequestrations of unipotent angioblastic cells (ARIEL & PACK 1960) They are usually divided into the following groups Hemangioendotheliomas, capillary and cavernous hemangiomas The main difference between the groups is the amount of endothelial cells and the size of the blood filled spaces Most authors describe the presence of a maturing process via the cavernous type to spontaneous remission, that corresponds with the occurrence of hemangiomas of mixed type in the liver, i e with centres of different degree of maturation The lesion must be regarded as benign in most cases, although sometimes it has a clinically malignant course The description of metastases by some authors is regarded by others as multicentric development of new growths and not as metastases The exact incidence is not known McLOUGHLIN (1971) has mentioned a frequency of approximately 0 35 per cent of cavernous hemangiomas in autopsies, but the tendency for spontaneous remission makes such a statement uncertain

Hemangioendotheliomas, particularly the mixed type, are most common in children

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The cavernous type more often occurs in adults with a predomination of females in a ratio of 9:1 (PANTOJA 1968). The hemangiomas are usually small and multiple, but may be diffuse throughout one lobe or the whole liver. They are commonly accompanied by hemangiomas of the skin. The histology is described by CROCHER & CLELAND (1957), DEHNER & ISHAK (1971) and EDMONDSON (1956) and others.

The clinical symptoms may be abdominal discomfort with enlargement of the liver, and cardiac failure in small infants. Thrombocytopenia and hemorrhage following rupture or necrosis may occur, but many angiomas are found accidentally at angiography. A large number of liver hemangiomas probably exist without any clinical symptoms (TAVERNIER et coll., REUTER & REDMAN 1972).

A warning must be given against any attempt at biopsy because of the great danger of a massive hemorrhage (KAGAN et coll. 1971, PANTOJA). Angiography is thus the best and safest procedure for arriving at the correct diagnosis, and the best results are obtained with selective coeliac angiography.

Treatment. Concerning treatment, the natural tendency for spontaneous remission is well recognized. When surgery is contemplated (e.g. local exision, lobectomy or ligation of a feeding artery), angiography is of great value in determining the exact anatomy of the lesion (TAVERNIER et coll.). The use of radiation therapy is discussed by many authors and treatment with steroids is suggested in combination with radiation therapy by DEHNER & ISHAK. One successful case treated with steroids and cardiac treatment is reported by GOLDBERG & FONKALSRUD (1969). The prognosis is generally good but there is the possibility of cardiac failure, and hemorrhages may be fatal.

Radiographic findings. An enlarged liver or an elevated or abnormally domed right hemidiaphragm may sometimes be found on a conventional film of the abdomen. Calcific deposits appearing as scattered irregular flecks of calcium, placed in the septa may occur. Calcified phleboliths are rarely seen (MCLOUGHLIN, PANTOJA).

The angiographic appearance has been described several times and in reviewing the literature the following points seem to be established: the best known and most common angiographic finding is that of the cavernous hemangioma (among others DIJKEN et coll. 1971, MCLOUGHLIN, PANTOJA, POLLARD et coll. 1966, TAVERNIER et coll.). The coeliac and the hepatic arteries are of normal size and appearance, but may be displaced around masses or crowded together. Late in the arterial phase, irregular areas of contrast medium appear to form labyrinths of pools or lakes, usually well demarcated, arranged in clusters or rings, often with an avascular centre. The retention of the contrast medium in these spaces lasts a long time, up to 30 seconds, and the venous phase is delayed. KAGAN et coll. and ROSCH & STECKEL (1972) report slight dilatation of the coeliac artery and the feeding hepatic arterial branches.

The other condition, often described, is hemangioendothelioma in newborn and small infants (BERDON & BAKER 1969, MOSS et coll. 1971, SELKE & CORWELL 1969, PANTOJA). The feeding coeliac and hepatic arteries are enlarged, the circulation rate is increased and bizarre irregular spaces surrounding large avascular areas are rapidly

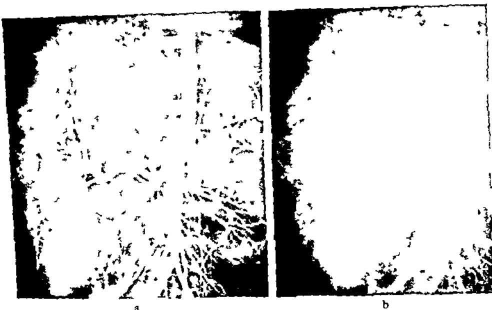


Fig 1 Case I a) Abdominal aortography Enlarged liver with stretched hepatic arteries of normal width b) Capillary phase Numerous irregular pools of contrast medium

filled The fast venous filling after about one second indicates the presence of arteriovenous shunting Moss et coll found numerous pathologic vessels in the arterial phase Most of these children had cardiac insufficiency and several died but in many cases no cardiac malformation was found It seems that the great amount of blood shunted through the liver overburdens the heart

The last condition the capillary hemangioma, resembles the hemangioendothelioma and several authors do not distinguish between the two types According to TAVERNIER the capillary hemangioma has normal sized feeding arteries The seemingly avascular masses surrounded by irregular vascular spaces with a rapid shunting of blood to the veins resemble the appearances of hemangioendothelioma, but there may be a more homogeneous appearance of the liver as well The avascular hemangioma (WATSON & BALTAXE 1971) may be of this type The avascular masses are thought to be areas with a large amount of endothelium compressing the vascular channels

The angiographic appearance with mixed endothelio-capillary and cavernous elements corresponds to the theory of maturing. The proportion between the two elements decides the type but the sudden jump from arteriovenous shunt to delayed venous filling in the cavernous type is difficult to understand and no explanation for this is found in the literature It could be caused by the increasing width of the vascular bed when small capillaries are replaced by wide cavernous lakes At the same time there may be some thrombosis in the irregular arteriovenous shunts Extensive intravascular coagulation in hemangiomas of the liver is described by DIJKEN et coll

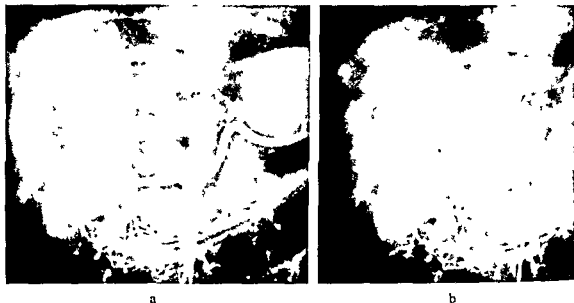


Fig 2 Same case as in Fig 1 a) Selective coeliac angiography 2 5 years later Regression following steroid treatment b) Capillary phase Only two small areas of cavernous hemangiomas

Case reports

Case 1 A girl born three weeks prematurely was fully developed with a weight of 3040 g At 3 weeks of age hemangiomas of the skin were observed and one week later, a tendency to vomit developed When 5 months old the girl became agitated with coughing, and one month later a right abdominal mass was detected, extending into the left hypochondrium The girl was admitted to hospital and an anaemia was found, Hb 8 2 g % Cardiac and liver function was normal Angiography was performed via the femoral artery Abdominal aortography was carried out with injection of 12 ml of Isopaque 260 The proximal part of the aorta was displaced to the left The liver was enlarged and the hepatic arteries stretched but of normal size (Fig 1 a) In the capillary phase numerous irregular pools were filled, partly diffuse and partly arranged in nests with a maximum diameter of 22 mm with an avascular centre Later some diffuse filling occurred, but no veins were observed during the 11 seconds the examination lasted (Fig 1 b) The spleen was enlarged and had, in the capillary phase, an appearance similar to that of the liver, suggesting that it also contained a hemangioma

Treatment with steroids was begun After 3 months the hemangiomas of the skin began to fade and after a further 3 months, regression of the abdominal mass was observed The treatment lasted 11 months with reduction of the dose after 3 months Steroid face (as in Cushing's disease) and reduction in growth rate developed but both returned to normal when the treatment ended

At 3 years of age the girl was re-admitted She was 5 cm shorter in height than the average for her age, but otherwise appeared healthy There was no hepatic or splenic mass Angiography now demonstrated marked regression with only a few small hemangiomas of cavernous type It was carried out as a selective coeliac angiography, using the same type and amount of contrast medium as at the previous angiography The aorta was in a normal position The liver and spleen were reduced in size compared with the first examination The hepatic arteries were corkscrew-shaped indicating a reduction in size of the liver (Fig 2 a) The capillary phase had a normal appearance except for two small circles, maximum



a



b

Fig 3 Case 2 a) Selective coeliac angiography Ectatic hepatic artery instant filling of a large hemangioma b) Capillary phase irregular areas of contrast medium

size 8 mm with a dense collection of pools of contrast medium (Fig 2 b) The veins filled at the end of the examination which lasted for 10 seconds

Case 2 A girl born prematurely with a birth weight of 2500 g There was some slight postnatal jaundice and some oedema of the right leg which disappeared spontaneously At 2 years of age she was examined because of hemangioma like changes in the left arm and leg When 3 years old hepatomegaly was detected At 6 years of age she was again admitted to hospital Hemangiomas in the face and left arm were noticed and at angiography a huge hemangioma of the liver was found The angiography was carried out with Isopaque 350 starting with 20 ml in the abdominal aorta After seeing the huge process 40 ml were injected selectively into the coeliac axis demonstrating some ectasy of the hepatic artery Rapid filling of numerous vessels was seen throughout almost the whole liver which was enlarged (Fig 3 a) Irregular areas of contrast medium appeared in some places arranged in circles or rings and at other sites scarcely visible (Fig. 3 b) Pool forming was slight and a delicate ...
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... same appearance with the same lateral border as seen previously (Fig 4 b) No venous filling was observed

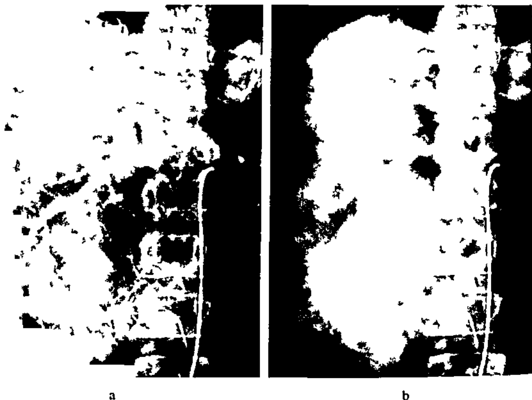


Fig 4 Same case as in Fig 3 a) Selective coeliac angiography 6 years later Further growth of the hemangioma b) Capillary phase has the same appearance as 6 years earlier

Discussion

Both patients had hemangiomas of the skin and an abdominal mass The first presented with anemia and vomiting but the second had no symptoms at all With the exception of the anaemia no pathology was found in laboratory tests of blood and urine in both cases

The first patient at her first angiography had a large hemangioma involving the whole liver and probably the spleen as well The hemangioma resembled the one described by BERDON & BAKER as a giant hepatic hemangioma It was large and had many irregular vascular pools but only some were arranged in the characteristic configuration of the cavernous hemangioma There were avascular areas but no dilatation of arteries or shunting to veins as is characteristic in hemangioendotheliomas The hemangioma could be in an early stage of maturation having left the endotheliomatous form but not quite reached the cavernous form At the second examination after steroid treatment for 11 months extreme regression had occurred as only *two minute cavernous elements were left The rest of the liver and spleen* was normal

In the second patient the hemangioma was of a more capillary type The absence of shunting and shortage of pools were not concordant with hemangioendothelioma

or cavernous hemangioma, but it also differed from the usual description of the capillary hemangioma This patient was not treated and experienced no discomfort, although the hemangioma grew in size

The main differential diagnosis is of hepatoma, where the feeding arteries are dilated, new formed irregular tumour vessels are present and the circulation is rapid with early venous filling (Moss et coll , TAVERNIER et coll)

The second differential diagnosis is multiple metastases, which also have wide feeding arteries with irregular courses and tapering, tumour vessels, pools and rapid venous filling These lesions are often multinodular (TAVERNIER et coll , WATSON & BALTAXE 1971)

Conclusion

Different angiographic appearances of the hepatic hemangiomas, one previously not described, were encountered in these two patients The maturation may vary between different parts of the tumour which results in varying width and course of the arteries avascular areas alternate with irregular arrangements of lakes or pools, and the veins may be rapidly filled by shunts or their filling may be delayed The presence of variation may explain the differences in previous descriptions and the lack of knowledge of the condition mentioned by Moss et coll

The fact that under steroid treatment, the lesion regressed, and without treatment, increased in size like a tumour, is interesting even with the process of maturation in mind Yet nothing conclusive can be said about treatment from this fact No microscopy was obtained in our cases, and any attempt at biopsy has to be condemned Angiography should replace histology in the diagnosis and control of this condition

SUMMARY

Two cases of hepatic hemangiomas are described diagnosed by angiography and controlled by repeat angiography after 2 5 and 6 years, respectively The radiologic appearance is described and although it varies angiography must be considered the safest method of diagnosis biopsy is contraindicated Steroid therapy seems to be a possible mode of treatment

ZUSAMMENFASSUNG

Zwei Fälle mit einem Hamangiom der Leber werden beschrieben [illegible] graphie untersucht und 2,5 bzw 6 Jahre später mi [illegible] Obwohl die Rontgenbefunde variieren, muss Angio [illegible] Methode angesehen werden Biopsie ist kontraindiz [illegible] mögliche Behandlungsmethode vorgeschlagen

RÉSUMÉ

Description de 2 cas d'hémangiome hépatique diagnostiqués per angiographie et controles par des angiographies répétées au bout de 2,5 et 6 ans Les auteurs décrivent l'aspect radiologique, bien qu'il soit variable, l'angiographie doit être considérée comme la methode de diagnostic la plus inoffensive La biopsie est contre-indiquée Les auteurs signalent une eventuelle technique de traitement avec des stéroïdes

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CORONARY ANGIOGRAPHY WITH DIATRIZOATE AND METRIZAMIDE

Comparison of ionic and non-ionic contrast medium effect on coronary blood flow in dogs

B TRÄGÅRDH, P LYNCH and MONIKA TRÄGÅRDH

Contrast medium delivered into the coronary arteries affects various heart functions (BROWN 1967, *FISCHER 1968)* and also produces alterations of the coronary blood flow Most authors report an initial brief decrease of the flow after the coronary injection *of a contrast* medium (LEHAN et coll 1963, FRIESINGER et coll 1965, TALBERT et *coll 1959) and they all* agree that a subsequent large and protracted increase in the flow occurs *(CARSON* et coll 1969 GUZMAN & WEST 1959, KLOSTER et coll 1972) *This increase* in flow is usually attributed to the hyperosmolarity of the medium or the chemical toxicity of its anion (HILAL 1966, LINDGREN & TÖRNELL 1958)

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The blood flow changes induced by the medium are important for several reasons, one is that experimental or clinical conclusions about blood flow made from observations of the flow of a contrast medium may be influenced by alterations of flow induced by the medium itself (NYLANDER 1967, RUTISHAUSER et coll 1970) Another

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reason is that alterations in coronary blood flow may change the myocardial contractility (NAKANO 1966) The flow of contrast medium through the coronary arteries, capillaries and veins as a bolus gives the most useful angiograms If a contrast medium flows faster through some areas of the vascular bed it will not simultaneously reach the larger veins and the quality of the phlebograms will be reduced

Metrizamide (Amipaque) is a recently developed non-ionic contrast medium with low osmolality and low intravenous toxicity (HOLTERMANN 1973, SALVESEN 1973) It has less effects on the contractility of the myocardium (TRÄGÅRDH et coll 1975 a, b) and on the electrical function of the heart (TRÄGÅRDH et coll 1974) than some of the current ionic media It produces a less increase of the blood flow than some of the commercially available ionic contrast materials when injected into the femoral artery in dogs (ALMÉN & TRÄGÅRDH 1973) However, its effects on the coronary blood flow have not been investigated previously Therefore, it seemed of interest to compare the flow changes and their consequences for the vascular appearances at angiography when metrizamide (non-ionic) and diatrizoate (ionic) are injected into the left coronary artery of anesthetized dogs

Material and Methods

Fourteen mongrel dogs weighing 13 to 22 kg were used They were anesthetized with an intravenously administered sodium pentobarbital dose of 32 mg/kg body weight In addition to this, the animals were given 200 IU heparin/kg body weight

The curved and tapered tip of an Ödman-Ledin catheter (*ID/OD – 1 4/2 2 mm*) was inserted from a carotid artery into the main left coronary artery during fluoroscopy The animal was moved onto a cut film changer (AOT, Elema-Schönander) In random order 4 0 ml sodium meglumine diatrizoate (Renografin 76) and 4 0 ml metrizamide (Amipaque) with the same iodine concentration of 370 mg I/ml were injected into the left coronary artery A Viamonte-Hobbs Injector delivered the media at a speed of 0 8–1 0 ml/s During each injection a series of films was exposed with a rate of one film per second The interval between subsequent injections was always 20 minutes The contrast media were preheated to 37° At this temperature the diatrizoate solution has a viscosity of 8 6 cP and an osmolality of 2 1 mol/kg, the metrizamide solution a viscosity of 15 7 cP and an osmolality of 0 6 mol/kg (BODALEN et coll 1970, HOLTERMANN 1974)

After completion of the filming procedures the catheter tip was immediately withdrawn into the aorta Nine of the dogs were subjects to the following procedure Through a midsternal incision the heart was exposed and a Harvard Respirator was connected to an inserted tracheal cannula The proximal section (about 2 cm) of the circumflex branch of the left coronary artery was isolated and the fat surrounding the vessel was carefully removed A flow probe with a diameter of 2 0 mm was fitted externally onto the coronary artery and connected to an electromagnetic flowmeter (Biotronex Laboratory Pulsed-Logic Blood Flowmeter)

Four of the nine thoracotomized dogs were subjects to the following additional procedure Following bilateral exposure of the jugular veins, soft polyethylene catheters (ID/OD = 3 0/4 5 mm) were inserted One catheter was placed in the jugular vein approximately 5 cm toward the heart Another antegrade catheter was introduced into the right jugular vein and led into the right atrium of the heart guided by a finger which manipulated it into the coronary sinus A ligature was sewn around the sinus tying the catheter securely into this structure forcing all the sinus blood through the catheter The catheter was in turn connected to a cannulating internal flow probe From the probe the blood returned to the animal via the other catheter previously inserted into the left jugular vein The artery flow probe was then attached as described above

After the surgery had been performed and the flow probes were functioning properly, the Ödman Ledin catheter was replaced into the main left coronary artery of the nine dogs At 15 minute intervals injections were performed with 4 0 ml of the same contrast media as was previously used during the filming procedure All the nine animals were also given 4 0 ml of metrizamide to which was added 13 5 mEq/l calcium ions as calcium chloride Six of the nine dogs were given 4 0 ml glucose solution 5 % The order of injections was random The blood flow was recorded for at least 20 seconds before and for 60 seconds after the start of each injection and thereafter, brief recordings were made after 2 and 3 minutes

ECG (lead II) was recorded on all animals Tracings from the flow meter and ECG were registered on an Electronics for Medicine Recorder

The electromagnetic flow meter displayed both phasic flow and mean flow Both flow types were recorded from the artery flow probe The characteristic recordings of the systolic and diastolic flow in the coronary artery indicated the proper position of the probe All reported flow values given in the results were obtained from the mean flow recordings The constancy of the preinjection flow was checked by measuring the preinjection flow at several points on the paper recordings The flow was measured at one second intervals for 20 seconds and thereafter measured 25, 30, 45 and 60 seconds *after the start* of the injection on the continuously running paper recording The flow was measured also on the 2 and 3 min recordings The flow values were expressed in per cent of the preinjection value (= 100 %)

Only mean flow was recorded from the coronary sinus flow probe The measurements were performed as described for the artery flow probe

The flow probes were calibrated with the aid of a Sigma motor pump and flask of heparinized blood The flask was connected to the pump via a catheter From the pump the blood was passed through another catheter and through the cannulating sinus probe After the passage of the probe the blood was collected in a graduated glass cylinder and then returned to the flask The artery probe was calibrated by passing the blood from the pump into an isolated femoral artery

The films were evaluated as follows The time in seconds was determined between the start of the injection and the moment when the coronary sinus was (a) first filled,

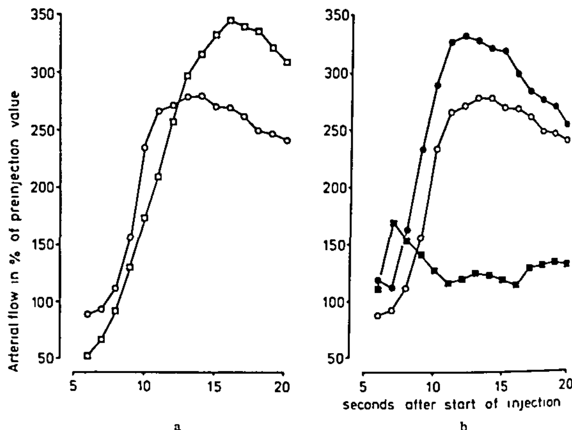


Fig 1 Electromagnetic arterial flow probe recordings at 2-second intervals after injection of 4 ml diatrizoate, metrizamide, metrizamide-calcium and glucose 5 % respectively into the left coronary artery Mean values from 9 dogs a) □ diatrizoate, ○ metrizamide b) ● metrizamide-calcium, ○ metrizamide, ■ 5 % glucose

(b) maximally filled and (c) when it still contained observable contrast medium Transit time was calculated as the period between start of injection and the first film without contrast medium visible in the coronary sinus The film with maximum filling of the sinus in the diatrizoate series was compared to the equivalent one in the metrizamide series and the difference in concentration of the contrast medium in the sinus evaluated according to a 4-grade scale (0 = none, + = low, + + = high, + + + = very high)

Results

Electromagnetic flow measurements In the arterial flow probe an initial decrease of flow occurred during the injection of the contrast medium After the end of the injection the flow rose immediately and exceeded the control value after 1 to 3 seconds after the end of the injection The flow continued to rise to a maximal value 11 to 20 seconds after start of injection Thereafter the flow slowly returned to the preinjection value which it reached after about 120 seconds The mean percentile arterial flow values for the injected media appear in Fig 1 for every second 6 to 20 seconds after the start of the injection

Table 1

Maximum flow increase (in per cent of preinjection value) and the time of this maximum (in s) after the start of the injection of 4 0 ml contrast materials and glucose into the left coronary artery in dogs Means and standard error of mean (SEM) are given

	Artery probe			Coronary sinus probe		
	Max flow	SEM	s	Max flow	SEM	s
Diatrizoate	358	58	16 8	172	21	13 8
Metrizamide	286	42	13 1	155	19	11 3
Metrizamide-calcium	351	52	12 8	163	20	11 8
Glucose 5 %	208	67	8 0	—	—	—

A significantly smaller ($p<0\ 01$) increase of arterial flow occurred after the injection of metrizamide (mean max increase 286 %) than after either an injection of a diatrizoate solution (mean max increase 358 %) or a metrizamide-calcium solution (mean max increase 351 %) Table 1 gives the mean maximal increase of arterial and coronary sinus blood flow for the various substances and at which mean time after the start of the injection these maxima occurred The glucose solution did not produce any initial decrease and mean maximum increased flow occurred only 8 seconds after the start of the injection, the maximum increase being significantly smaller ($p<0\ 05$) than for metrizamide

The mean percentile coronary sinus flow values for diatrizoate and metrizamide are displayed in Fig 2 in one-second intervals for the first 20 seconds after the start of the injection Some initial decrease of the sinus flow was encountered after the injection of metrizamide, but diatrizoate did not produce any reduction of flow at all The increase of sinus flow occurred simultaneously with the flow increase in the arterial flow probe Metrizamide and diatrizoate produced the same relative difference of maximal flow increase at both flow probes

Film evaluation All films were of good quality The venous filling was much better with metrizamide than with diatrizoate, the difference in degree of filling was always in favor of metrizamide and the outline of the contrast medium along the sinus vessel wall was more distinct with metrizamide than with diatrizoate (Fig 3, Table 2) No difference between the contrast media could be seen with regard to the demonstration of the arteries or capillaries The observations of the transit time appear in Table 2 It is evident that diatrizoate leaves the arteries later than metrizamide ($p<0\ 025$) and also leaves the coronary veins later than metrizamide ($p<0\ 01$) The transit time for metrizamide is mean 10 5 s, for diatrizoate mean 12 1 s The difference is significant ($p<0\ 01$)

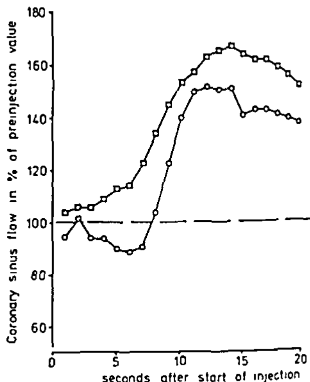
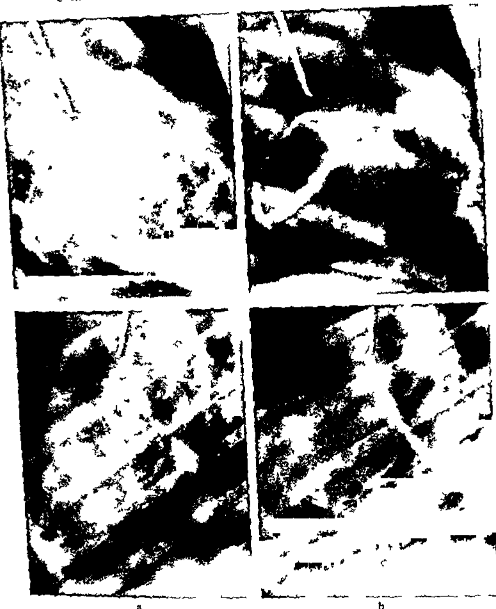


Fig 2 Electromagnetic coronary sinus flow probe recordings at 2 second intervals after injection of 4 ml diatrizoate and metrizamide Mean values from 4 dogs □ diatrizoate, ○ metrizamide

Discussion

Electromagnetic flow recordings Contrast medium introduced into an artery produces an increased blood flow (HILAL 1966, LINDGREN & TÖRNELL 1958) A protracted increased coronary blood flow has also been found after the injection of a medium into a coronary artery (FRIESINGER et coll 1965, KLOSTER et coll 1972, TALBERT et coll 1959) This is usually attributed to the hyperosmolarity of the contrast material or to the chemical toxicity of its anion (HILAL, LINDGREN 1970) Metrizamide is a non-ionic contrast medium with low osmolality (HOLTERMANN), and it has been observed to produce a smaller increase in femoral blood flow than some of the commercially available ionic media (ALMEN & TRÄGÅRDH 1973) The present investigation establishes the fact that after an injection into the left coronary artery in dogs, metrizamide produces less increase in coronary blood flow than the more hyperosmolar medium diatrizoate (Table 1) The recordings from the artery flow probe and the coronary sinus probe were in good agreement These different flow effects of the two media may be explained by the considerable difference of osmolality between metrizamide and the ionic medium diatrizoate

However, the addition of calcium chloride to metrizamide resulted in an increased effect on the flow while changing the osmolality only slightly (Fig 1 b) The flow effects of metrizamide-calcium were equal to those of diatrizoate in spite of the fact that the added osmolality was below 4 per cent The calcium chloride seems to have a direct effect on flow besides its osmotic effects LINDGREN et coll (1967) have found no similar effects for either calcium or magnesium ions They added



F g 3 Maximum f ll ng of the coronary s nus of the same dog after inject on of a) 4 ml d atrizoate and b) 4 ml metrizamide

calc um and magnes um ions to a sodium chloride solution 4 2 % or to metrizoate The osmot c effect of thes solutions is about the same as of the present d atrizoate solution On the other hand in the present investigation calcium ions were added to metrizam de with considerably lower osmolal ty so that the effect of calcium ions was not camouflaged by great osmotic effects

Table 2

Transit times (in seconds) of contrast medium evaluated from coronary angiograms with diatrizoate and metrizamide Mean and standard error of mean (SEM) are given The probability for rejection of the zero hypothesis is calculated with paired t tests

	Diatrizoate		Metrizamide		p for rejection of zero hypothesis
	Mean	SEM	Mean	SEM	
Still remaining in any artery	7 6	0 5	6 4	0 3	<0 025
First seen in coronary sinus	6 4	0 3	6 4	0 3	NS
Maximum conc in the coronary sinus	8 6	0 4	7 8	0 4	NS
Still seen in coronary sinus	11 4	0 4	9 5	0 3	<0 01
Transit time	12 1	0 4	10 5	0 3	<0 01

Metrizamide-calcium has been found to have less effect on myocardial contractility than pure metrizamide (TRÄGÅRDH et coll 1975 a, b) One possible explanation may be that the toxic effects on contractility by the metrizamide molecule per se, is counterbalanced by the simultaneously increased blood flow, induced by the calcium ions, producing a more intense perfusion with normal nutritive fluid (KLOSTER et coll 1972)

Most authors (LEHAN et coll 1963, RUTISHAUSER et coll 1970, TALBERT et coll 1959) have found the increased flow preceded by a brief reduction of arterial flow after injection of an ionic contrast medium into the coronary artery GUZMAN & WEST (1959) found a contrast-medium-induced increase of coronary sinus flow, but did not mention a preceding reduction of the flow In our arterial blood flow probe a considerable flow reduction occurred initially during the injection of the contrast medium The electromagnetic artery flow probe recordings may be less reliable, as during the injection period the blood in the vessel is completely replaced by contrast medium with electrical properties much different from blood, which may influence the probe signals (SPENCER & DENISON 1959) The changes of the electrical properties of the vessel walls do not affect the cannulating sinus probe, and the contrast medium is also more diluted by blood from the other coronary artery which flows into the coronary sinus Therefore, the sinus probe may be expected to give more reliable data However, the inflow of blood into the sinus from the coronary artery which did not receive contrast medium would reduce the changes in flow in the sinus Consequently, any differences would be difficult to detect The flow registered from the sinus probe was not reduced during the diatrizoate injection, but during the metrizamide injections a brief and small (less than 15 %, Fig 2) reduction of the flow occurred This difference between the two media in initial flow reaction could possibly be caused by the greater viscosity of the metrizamide solution

Influence of flow changes on the film quality The question arises whether the transit time of the contrast medium through the vascular bed and the concomitant changes of the flow of medium and blood affect the quality of the films It would appear that a desirable contrast medium would pass through the vessels as a bolus giving an optimum filling of arteries, capillaries and veins The quality of the venous filling may be expected to be dependent on the simultaneous transition of the medium through all the capillaries to the veins (BOIJSEN 1967) An overall increased coronary blood flow would tend to dilute the contrast bolus and deliver it earlier to the venous collecting vessels

Based on the evaluations of the films it was found that all contrast media had left the cardiac vessels after a mean transit time of 10 5 s for metrizamide, and 12 1 s for diatrizoate (Table 2) During this period no significant difference between the recorded electromagnetic flow tracings occurred induced by either of the two types of media (Fig 1 a) However, the analyses of the films reveal that metrizamide appears in the coronary sinus at the same time as diatrizoate The difference is that the metrizamide has completely left the arteries earlier than diatrizoate and also completely left the coronary sinus earlier than diatrizoate It appears that some of the diatrizoate is trapped in the vessels whereas metrizamide passes through more like a confluent bolus

Microcirculatory investigations have shown that contrast media cause a dilatation and a paralysis of small vessels and an aggregation of blood cells producing sometimes a complete stop of the flow through these small vessels (ALMÉN & WIEDEMAN 1968, BRÅNEMARK et coll 1969) The prolonged transit time of diatrizoate could be explained by more marked effects when compared to metrizamide Several of these factors are less affected by metrizamide than by ionic contrast media (ALMÉN 1973)

During the transit through the vessels some contrast medium seems to leave the vascular space diffusing across the vessel wall (CARSON & LAZZARA 1970) It is possible that the non ionic metrizamide particles have less tendency than ionic contrast particles to such a diffusion Then the metrizamide bolus could be assumed to reach the veins more unaffected than the corresponding diatrizoate contrast bolus This may explain the delayed transit of diatrizoate through the smaller vessels It gives an account for the faster passage of metrizamide through all the vessels simultaneously, explaining the better filling of the coronary sinus

Conclusions

Following injection into the left coronary artery in dogs metrizamide gave a better filling of the veins than diatrizoate giving information about the condition of the cardiac veins This may improve diagnosis in cardiac disease (DATTA & GUPTA 1972) An increased quality of the phlebograms may be anticipated in angiography with metrizamide also in other vascular areas

Metrizamide was found to give rise to less blood flow increase than diatrizoate,

which could be a result of less vaso-dilatation and paralysis Conclusions about blood flow are sometimes made from observations of vessel diameters and transit times Contrast media themselves affect these parameters and as metrizamide seems to have smaller effects than ionic media, metrizamide may be expected to give more reliable flow data

Toxic effects of contrast media are probably related to the time the contrast medium remains in the vessels The less deleterious effects of metrizamide compared to diatrizoate and other ionic media on various heart functions could partly be explained by the observed shorter transit time for metrizamide through the coronary vessels

SUMMARY

The non ionic contrast medium metrizamide produced a smaller coronary flow increase than the ionic medium diatrizoate after injection into the main left coronary artery in dogs and had also a shorter transit time through the coronary vessels The coronary veins were better filled with metrizamide The reduced coronary flow effects of metrizamide compared to ionic contrast medium and the improved venous filling makes metrizamide a favorable contrast material for use in coronary angiography

ZUSAMMENFASSUNG

Das nicht-ionisierte Kontrastmittel Metrizamid verursachte einen geringeren Anstieg der Koronardurchblutung als das ionisierte Mittel Diatrizoate nach Injektion in die A coronaria sinistra des Hundes und hatte auch eine kurzere Durchstromungszeit durch die Koronargefasse Die Venen fullten sich besser mit Metrizamid Die geringere Wirkung auf die Koronardurchblutung von Metrizamid verglichen mit dem ionisierten Kontrastmittel und die bessere venose Fullung machen Metrizamid zu einem vorteilhaften Kontrastmittel zur Koronarangiographie

RÉSUME

Le moyen de contraste non-ionique métrizamide injecté dans l artère coronaire gauche principale sur des chiens, donne lieu à une augmentation du debit coronaire inferieure à celle que cause le moyen de contraste ionique diatrizoate Le métrizamide a aussi un temps de transit plus court a travers les vaisseaux coronaires Les veines coronaires sont mieux remplies par le métrizamide Les effets reduits du métrizamide sur le débit coronaire par rapport aux effets du moyen de contraste ionique et l'amélioration du remplissage des veines font que le métrizamide est un bon moyen de contraste pour l'angiographie coronaire

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which could be a result of less vaso-dilatation and paralysis Conclusions about blood flow are sometimes made from observations of vessel diameters and transit times Contrast media themselves affect these parameters and as metrizamide seems to have smaller effects than ionic media, metrizamide may be expected to give more reliable flow data

Toxic effects of contrast media are probably related to the time the contrast medium remains in the vessels The less deleterious effects of metrizamide compared to diatrizoate and other ionic media on various heart functions could partly be explained by the observed shorter transit time for metrizamide through the coronary vessels

SUMMARY

The non ionic contrast medium metrizamide produced a smaller coronary flow increase than the ionic medium diatrizoate after injection into the main left coronary artery in dogs and had also a shorter transit time through the coronary vessels The coronary veins were better filled with metrizamide The reduced coronary flow effects of metrizamide compared to ionic contrast medium and the improved venous filling makes metrizamide *a favorable* contrast material for use in coronary angiography

ZUSAMMENFASSUNG

Das nicht ionisierte Kontrastmittel Metrizamid verursachte einen geringeren Anstieg der Koronardurchblutung als das ionisierte Mittel Diatrizoate nach Injektion in die A coronaria sinistra des Hundes und hatte auch eine kurzere Durchstromungszeit durch die Koronargefässe Die Venen fullten sich besser mit Metrizamid Die geringere Wirkung auf die Koronardurchblutung von Metrizamid verglichen mit dem ionisierten Kontrastmittel und die bessere venose Fullung machen Metrizamid zu einem vorteilhaften Kontrastmittel zur Koronarangiographie

RESUMÉ

Le moyen de contraste non ionique métrizamide injecte dans l artere coronaire gauche principale sur des chiens donne lieu à une augmentation du debit coronaire inferieure à celle que cause le moyen de contraste ionique diatrizoate Le métrizamide a aussi un temps de transit plus court à travers les vaisseaux coronaires Les veines coronaires sont mieux remplies par le métrizamide Les effets reduits du métrizamide sur le débit coronaire par rapport aux effets du moyen de contraste ionique et l amélioration du remplissage des veines font que le métrizamide est un bon moyen de contraste pour l angiographie coronaire

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CONTRAST MEDIA

Quantitative criteria for designing compounds with low toxicity

H LEVITAN and S I RAPOPORT

Recently, it was demonstrated that clinical and experimental toxicities of contrast media that are iodobenzoic acids or their derivatives are correlated with their lipid solubilities (RAPOPORT & LEVITAN 1974) It was suggested that relative toxicities arose from relative rates of entry into the brain across the blood brain barrier, since barrier permeability to solutes is known to increase with increasing lipid solubility (CRONE 1965) The blood brain barrier at cerebral blo[illegible] of endothelial cells that are connected by tight [illegible] ties like many cell membranes (REESE & KAR[illegible] 1964)

Lipid solubility is measured by the octanol/water partition coefficient of a compound The partition coefficient is an additive constitutive property and can be estimated accurately for derivatives of a compound whose partition coefficient is already known (HANSCH 1971, LEO et coll 1971) The design of contrast media with lower partition coefficients than those in current clinical use will be discussed in the present report On the basis of the correlation between toxicity and lipid solubility, it is suggested that these media may also be less toxic

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Table 1

Relation of systemic toxicity in mice to lipid solubility of iodobenzoic acid derivatives. P_{HA} is the octanol water partition coefficient of the undissociated acid calculated from the experimental value for benzoic acid ($\log P_{HA} = 1.87$) and Π substituent constants (FUJITA et coll., LEO et coll.). P^* is the partition parameter for the agent at pH = 7.4 calculated by Eq. 3 letting $pK_a = 6.97$ for compound 1, 4.75 for 2, 4.92 for 3 and 3.0 for compounds 4 to 20. LD_{50} were taken from WALLINGFORD et coll. BZ = benzoic acid

Compound	Log P_{HA}	Log P^*	LD_{50} (mM/kg) (observed)	Log $1/LD_{50}$ (observed)
1 BZ,2 NH_2,3,5-Di I	3.77	3.20	0.438	0.359
2 BZ,3 NH_2-2,4,6-Tri I	2.48	−0.13	2.700	−0.432
3 BZ,4-NH_2 3,5-Di I	3.14	0.67	1.253	0.098
4 BZ,2 Acetylamino-3,5-Di I	4.44	0.74	3.377	−0.529
5 BZ,2 Butyrylamino-3,5-Di I	5.44	1.75	1.159	−0.064
6 BZ,2-(N Caproylamino)-3,5-Di I	6.44	2.74	0.717	0.145
7 BZ,2 Benzoylamino-3,5-Di I	6.53	2.83	0.699	0.156
8 BZ,2-(γ Phenylbutyrylamino)-3,5-Di I	6.93	3.23	0.691	0.161
9 BZ,2-(2 1 Benzoylamino)-3,5-Di I	7.45	3.75	0.896	0.048
10 BZ,3 Formylamino-2,4,6-Tri I	3.28	0.64	14.159	−1.150
11 BZ,3 Acetylamino-2,4,6-Tri I	3.29	0.63	16.511	1.218
12 BZ,3 Propionylamino-2,4,6-Tri I	3.79	−0.13	13.659	−1.136
13 BZ,3 Butyrylamino-2,4,6-Tri I	4.29	0.37	7.908	0.898
14 BZ,3 Benzoylamino 2,4,6-Tri I	4.80	0.88	1.560	0.193
15 BZ,3 Iso-Butyrylamino-2,4,6-Tri I	4.09	0.17	6.096	0.785
16 BZ,3-Caproylamino-2,4,6-Tri I	5.29	1.37	2.283	−0.359
17 BZ,3 Caprylamino-2,4,6-Tri I	6.29	2.37	0.996	0.002
18 BZ,3 Lauroylamino-2,4,6-Tri I	8.29	4.37	0.403	0.394
19 BZ,4-Acetylamino-3,5-Di I	4.05	0.13	9.272	0.967
20 BZ,4-Benzoylamino-3,5-Di I	5.94	2.02	1.214	0.084

to equal 6.97, 4.78 and 4.92, respectively, the pK_a of the unsubstituted amino benzoic acids (WEAST 1970).

The relation of systemic toxicity $1/LD_{50}$ to the partition parameter for compounds 1 to 20 is plotted in Fig. 1 and may be represented by the following quadratic equation

$$\log(1/LD_{50}) = -0.816 + 0.511 \log P^* - 0.060 (\log P^*)^2 \quad (4)$$

This equation represents the data more significantly than does a simple linear fit ($p = 0.1$). The significance of the fit to the data is at the $p < 0.001$ level and the multiple correlation coefficient R equals 0.93. Since systemic toxicity of contrast agents is so highly correlated with lipid solubility, toxicity should be minimized further by reducing the value of the partition parameter P^*. This can be done by increasing the fraction of acid that dissociates at plasma pH, or by decreasing the hydrophobicity of substituents on the hydrocarbon ring.

Methods

Commonly used contrast agents are derivatives of 2,4,6-triiodobenzoic acid. The octanol/water partition coefficient of each of them is not known, but can be calculated from the observed partition coefficient of benzoic acid by additive-constitutive rules, according to the following equation (FUJITA et coll. 1964, HANSCH 1971, LEO et coll.),

$$\Pi_x = \log (P_{HA})_x - \log (P_{HA}) \quad (1)$$

Π_x describes the amount by which a substituent x increases or decreases the partition coefficient of a parent compound HA, in this case benzoic acid. Values of Π_x for a large number of additives have been published (LEO et coll.).

The pK_a of most di- and tri-iodobenzoic acids are between 2.7 and 3.0 (HOPPE et coll. 1967, NICKEL, personal communication, RAPOPORT & LEVITAN). In calculating their actual lipid solubility, not only the partition coefficient of the undissociated compound must be taken into account, but also the fraction of undissociated compound in solution, which is only about 0.002% of the total concentration at a plasma pH of 7.4.

A partition parameter P^* is defined to represent the overall tendency of the compound (dissociated and undissociated forms) to distribute in octanol rather than water. If P_{HA} is the partition coefficient of the undissociated form of an acid HA, and P_A the coefficient of the dissociated form, then P^* is the sum of the coefficients multiplied by the respective concentrations of undissociated and dissociated forms in solution (RAPOPORT & LEVITAN).

$$P^* = P_{HA}\frac{[HA]}{[HA]+[A]} + P_A\frac{[A]}{[HA]+[A]} \quad (2)$$

From the definitions of pK_a and of pH, it is possible to write P^* in terms of P_A and P_{HA} as follows,

$$P^* = P_{HA}\frac{1}{1+10^{(pH-pK_a)}} + P_A\frac{1}{1+10^{(pK_a-pH)}} \quad (3)$$

$P_A = 10^{-4.1}\ P_{HA}$ for benzoic acids and $10^{-3.8}\ P_{HA}$ for anthranilic acid derivatives (Table 1) (LEO et coll., HANSCH 1974).

Results

Reduction of toxicity by reducing lipid solubility

Table 1 represents the relation of systemic toxicity of 20 di- and tri-benzoic acids, as measured by the quantity $1/LD_{50}$, to the partition parameter P^* (WALLINGFORD et coll. 1952, RAPOPORT & LEVITAN). The values of P_{HA} for the compounds were calculated from P_{HA} of the parent benzoic acid ($\log P_{HA} = 1.87$) by employing published Π_x values for the additive constituents, according to Eq. 1. The pK_a were taken as 3.0 for compounds 4 to 20, while those for compounds 1 to 3 were assumed

Table 1

Relation of systemic toxicity in mice to lipid solubility of iodoben oic acid derivatives P_{HA} is the octanol water partition coeff cient of the undissociated acid calculated from the experimental value for ben oic acid (log P_{HA} = 1 87) and Π-substituent constants (FUJITA et coll, LEO et coll) P^* is the partition parameter for the agent at pH = 7 4 calculated by Eq 3 letting pK_a = 6 97 for compound 1 4 75 for 2 4 92 for 3 and 3 0 for compounds 4 to 20 LD_{50} were taken from WALLINGFORD et coll BZ = ben oic acid

Compound	Log P_{HA}	Log P^*	LD_{50} (mM/kg) (observed)	Log $1/LD_{50}$ (observed)
1 BZ,2 NH_2 3 5 Di I	3 77	3 20	0 438	0 359
2 BZ 3 NH_2 2 4 6-Tri I	2 48	−0 13	2 700	−0 432
3 BZ 4-NH_2 3 5 Di I	3 14	0 67	1 253	−0 098
4 BZ 2 Acetylamino-3 5 Di I	4 44	0 74	3 377	−0 529
5 BZ,2 Butyrylamino 3 5 Di I	5 44	1 75	1 159	−0 064
6 BZ,2-(N Caproylamino)-3 5 Di I	6 44	2 74	0 717	0 145
7 BZ,2 Benzoylam no 3,5 Di I	6 53	2 83	0 699	0 156
8 BZ 2-(x Phenylbutyrylamino)-3 5 Di I	6 93	3 23	0 691	0 161
9 BZ,2-(2 I Benzoylamino) 3 5 Di I	7 45	3 75	0 896	0 048
10 BZ,3 Formylamino-2 4 6-Tri I	3 28	−0 64	14 159	−1 150
11 BZ,3 Acetylamino-2 4 6-Tri I	3 29	−0 63	16 511	−1 218
12 BZ,3 Propionylamino-2 4 6-Tri I	3 79	−0 13	13 659	−1 136
13 BZ,3 Butyrylamino-2 4 6-Tri I	4 29	0 37	7 908	−0 898
14 BZ,3 Benzoylamino 2 4 6-Tri I	4 80	0 88	1 560	−0 193
15 BZ,3 Iso-Butyrylamino-2 4 6-Tri I	4 09	0 17	6 096	0 785
16 BZ,3 Caproylamino-2 4 6 Tri I	5 29	1 37	2 283	−0 359
17 BZ,3 Caprylamino-2 4 6-Tri I	6 29	2.37	0 996	0 002
18 BZ,3 Lauroylamino-2 4 6-Tri I	8 29	4 37	0 403	0 394
19 BZ,4-Acetylam no-3 5 Di I	4 05	0 13	9 272	−0 967
20 BZ,4-Benzoylamino-3 5 D I	5 94	2 02	1 214	−0 084

to equal 6 97, 4 78 and 4 92 respectively, the pK_a of the unsubstituted amino benzoic acids (WEAST 1970)

The relation of systemic toxicity $1/LD_{50}$ to the partition parameter for compounds 1 to 20 is plotted in Fig 1 and may be represented by the following quadratic equation

$$\log(1/LD_{50}) = -0\,816 + 0\,511 \log P^* - 0\,060 (\log P^*)^2 \qquad (4)$$

This equation represents the data more significantly than does a simple linear fit ($p = 0$ 1) The significance of the fit to the data is at the $p < 0\,001$ level and the multiple correlation coefficient *R equals* 0 93 Since systemic toxicity of contrast agents is so highly correlated with lipid solubility, toxicity should be minimized further by reducing the value of the partition parameter P^* This can be done by increasing the fraction of acid that dissociates at plasma pH or by decreasing the hydrophobicity of substituents on the hydrocarbon *ring*

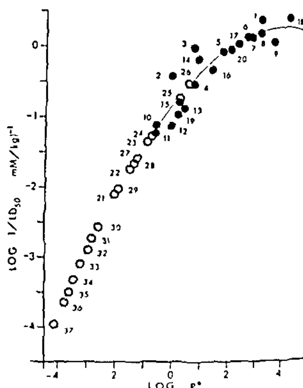


Fig 1 Systemic toxicity ($1/LD_{50}$) in mice of iodinated benzoic and benzene sulfonic acids as a function of partition parameter, P*. Compounds 1 to 20 (filled circles) are listed in Table 1 and represent LD_{50} obtained by WALLINGFORD et coll Compounds 21 to 26 (open circles) are the simple iodinated benzoic acids listed in Table 3 and their LD_{50} are predicted from Eq 4 Compounds 27 to 37 (open circles) are iodinated acids listed in Table 5 whose LD_{50}'s are also predicted from Eq 4 The line represents a plot of Eq 4

Dissociation constant

By decreasing pK_a for a series of organic acids, it is possible to make log P* more closely approach log P_A, since the unionized fraction becomes progressively negligible. A comparison of the pK_a of carboxylic and sulfonic acids reveals that, although unsubstituted aliphatic and aromatic carboxylic acids have pK_a of about 5 and 4, respectively, the pK_a of the corresponding sulfonic acids are less than 1 (Table 2). Other factors aside, log P* of a benzene sulfonic acid will be closer to log P_A than log P* of a benzoic acid, and the sulfonic acid may thus be less toxic.

Substituents on the hydrocarbon framework

Effect of iodination The addition of an iodine molecule to the benzene ring of benzoic acid increases the partition coefficient by a large amount (Table 3) While this is undesirable from the standpoint of toxicity, it remains essential for absorption of the radiation

Table 3 illustrates also that log P_{HA} of an iodobenzoic acid depends on the iodine position in the benzene ring The 3-iodobenzoate is more lipid soluble than the 4-iodobenzoate, which in turn is more lipid soluble than the 2-iodobenzoate The net effect is that the more iodinated and more radiation attenuating 2,4,6-triiodobenzoate is less lipid soluble than the less iodinated 3,5-diiodobenzoate, and it is therefore the compound of choice as a contrast medium

Since the addition of substituents IO (iodoso) and IO_2 (iodyl) reduces the log P_{HA}

Table 2

Comparison of dissociation constants of carboxylic and sulfonic acids

Compound	pK_a[a]
Benzoic	4 19
Benzene Sulfonic	0 70
Octanoic	4 89
Octane Sulfonic	<1 00[b]
2 Naphthoic	4 17
Naphthalene Sulfonic	0.57

[a] From WEAST
[b] From BRODIE

of benzene by 3 74 and 3 46, respectively (HANSCH et coll 1973 b), their use in place of iodide should lower the partition coefficients of the contrast media by about four orders of magnitude (with correspondingly lower toxicity), while retaining the requisite absorption capacity Aliphatic acids also could serve in principle as nuclei for iodination, but they are unsuitable as practical contrast agents because they are unstable when iodinated (HOEY et coll 1971)

Hydrophilic substituents in the 3 and 5 positions The partition coefficient of 2,4,6-triiodobenzoic acid can be reduced by placing hydrophilic substituents in the 3 and 5 positions of the benzene ring Table 4 lists Π_x substituent constants of several hydrophilic groups, as defined by Eq 1 Addition of the groups in the table to the meta positions of a triiodinated benzoic acid nucleus should reduce its partition coefficient by approximately the amounts shown

With the use of such substituents, it is possible to design compounds with partition parameters, P^*, at least two orders of magnitude less than benzoic acid itself Because of the high correlation between P^* and $1/LD_{50}$ (Eq 4), the toxicities of these compounds should also be significantly reduced, as is predicted by Table 5, and illustrated in Fig 1

Reduction of toxicity by reducing solution osmolality

Ionic contrast agents that are employed currently in cerebral angiography are very hypertonic, with osmolalities between 1 1 and 1 5 osmolal as compared to a normal plasma osmolality of 0 29 (RAPOPORT et coll 1974, BORDALEN et coll 1970) These hypertonic solutions decrease myocardial contractility, produce systemic hypotension and aggregate red blood cells (ALMEN 1971) Furthermore, they are concentrated enough to osmotically open the blood brain barrier, probably by shrinking cerebrovascular endothelial cells and widening the tight junctions that connect them (RAPOPORT 1973, RAPOPORT et coll)

Non ionic contrast media have been introduced recently with the same absorption

Table 3

Effect of iodination of benzoic acid on calculated partition parameter P and predicted systemic toxicity in mice, 1/LD50 Log P* was obtained from P_{HA} by means of Eq 3, letting $P_A = 10^{-4.1} P_{HA}$, and $pK_a = 3.0$ at pH = 7 4 Estimated toxicity was obtained by means of Eq 4, and plotted as compounds number 21 to 26 in Fig 1*

Compound	Log P_{HA}[b]	Log P*	Log 1/LD_{50} (predicted)	LD_{50}, mM/kg (predicted)
21 Benzoate (BZ)	1 87[a]	2 05	−2 12	132
22 BZ,2-I	2 4	1 52	−1 73	54
23 BZ,4-I	3 02	0 90	−1 33	21
24 BZ,3-I	3 14	−0 77	−1 25	18
25 BZ,2,4,6-Tri-I	4 08	0 16	−0 74	5
26 BZ, 3,5-Di-I	4 43	0 51	0 57	4

[a] From HANSCH (1974)
[b] Calculated using substituent constants from FUJITA et coll

Table 4

Π-Substituent constants of hydrophilic groups

Hydrophilic group	Π-Meta
-OH (hydroxyl)	0 38[a]
-NHCOCH3 (acetamido)	0 79[c]
-NH2 (amino)	1 19[a]
-CONH2 (carbamyl)	−1 49[b]
SO2NH2 (sulfamyl)	1 82[b]

[a] From benzoic acid system (FUJITA et coll)
[b] From benzene system (FUJITA et coll)
[c] From phenoxyacetate system (FUJITA et coll)

capacity as the ionic agents, but with half the osmolality They are formed by condensing either a hydroxylalkylamido group or a glucoseamido group with the -COOH of the corresponding tri-iodobenzoic acid Due to their lower tonicity, they should be less toxic both at the barrier and at the systemic circulation than the corresponding ionized contrast media

One of them, the glucoseamide of metrizoic acid (Metrizamide, Fig 2), has been shown to be less toxic by a factor of 2 than ionized metrizoate when administered systemically, and less toxic by a factor of 10 when applied directly to the brain (GONSETTE 1974, SALVESEN 1974) Its central toxicity depends however on the anesthetic agent that is employed (GREPE & WIDÉN 1974)

The octanol/water partition coefficient of Metrizamide is not published as far as we know Therefore log P* was estimated to equal −0 19 by the additivity rule of Eq 1 (Table 6) This value cannot be inserted into Eq 4 to predict systemic toxicity,

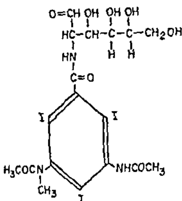


Fig 2 Structure of glucoseamide of metrizoic acid

since that toxicity lipid solubility relation applies to the homologous series of benzoic acid derivatives and probably to other organic anions also (LEVITAN & BARKER 1974), but not to non ionic compounds In fact, for a particular value of log P*, non ionic compounds are often biologically less active by two orders of magnitude than corresponding ionic compounds (BARKER & LEVITAN 1975, HANSCH & GLAVE 1971)

Discussion

In a recent review of diagnostic contrast agents, HOEY et coll enumerated properties which were important for an ideal contrast medium The first, maximum absorption capacity, is clearly achieved by iodination of the hydrocarbon substructure Although both aliphatic and aromatic iodinated compounds can be synthesized, aromatic compounds are preferred because their greater chemical stability decreases the likelihood of releasing inorganic iodine It is desirable also to minimize the increase in blood viscosity produced by contrast media, and synthesis should be designed so as not to increase molecular weight beyond acceptable limits and to obtain spherical molecules (ALMEN 1969)

The osmolality of the solutions of contrast media should also be minimized Concentrations greater than about 1 2 osmolal open the blood-brain barrier and increase the entry of the media and other solutes into the brain, and have substantial cardio vascular effects (ALMEN 1971, RAPOPORT et coll) Osmolality can be minimized by polymerization or by using glucoseamides of the benzoic acids, rather than the corresponding ionized salts (HILAL 1970, HOLTERMANN 1974)

The requirement that contrast media be pharmacologically inert can, to a large extent, be accommodated by minimizing the partition parameter P*, either by using ionized acids with low pK_a or by adding hydrophilic substituents to positions not occupied by iodine molecules in ionized and unionized agents On the basis of the established relation between toxicity and lipid solubility for the ionized agents, it is likely that toxicity of the corresponding unionized agents also depends on lipid solubility

Table 5

Calculation of partition parameters and predicted toxicities in mice for a series of iodo benzoic and iodo benzenesulfonic acids Log P_{HA} *was calculated by means of the additive-constitutive rule of Eq 1* Log P^* *was taken equal to* log P_A *for the benzene-sulfonic acids, which are almost completely ionized at* pH 7 4 Log P^* *was calculated from* P_{HA} $pK_a = 3\ 0$ *and* pH = 7 4 *by means of Eq 3 for the benzoic acids, letting* $P_A = 10^{-4\ 4} P_{HA}$ *Values of toxicity,* $1/LD_{50}$, *were estimated by means of Eq 4 from values of* log P^*, *and are plotted as a function of* P^* *in Fig 1*

	Compound Name	Substituents R_1	R_2	R_3	Calculation of Log P_{HA}
27	Metrizoate (Isopaque)	COOH	$N(CH_3)COCH_3$	$NHCOCH_3$	$\Pi_{2\,4\,6\text{ Tri I BZ}}$* + Π_{NHCOCH_3} + $\Pi_{N(CH_3)COCH_3}$ 4 08 − 0 79 − 0 69
28	Diatrizoate (Hypaque)	COOH	$NHCOCH_3$	$NHCOCH_3$	$\Pi_{2\,4\,6\text{ Tri I BZ}}$ + 2Π_{NHCOCH_3} 4 08 + 2(0 79)
29	Iothalamate (Conray)	COOH	$CONHCH_3$	$NHCOCH_3$	$\Pi_{\ 4\,6\text{ Tri I BZ}}$ + Π_{CONH_2} + $\Pi_{CH_3\text{ on }N}$ + Π_{NHCOCH_3} 4 08 − 1 49 + 0 16 − 0 79
30	Ioxitalamate (Vasobrix)	COOH	$CONHCH_2CH_2OH$	$NHCOCH_3$	$\Pi_{2\,4\,6\text{ Tri I BZ}}$ + Π_{CONHCH_3} + Π_{CH_2OH} + Π_{NHCOCH_3} 4 08 − 1 33 − 0 66 0 79
31	BZ,3,5-di CONH$_2$	COOH	$CONH_2$	$CONH_2$	$\Pi_{2,4\,6\text{ Tri I BZ}}$ + 2Π_{CONH_2} 4 08 + 2(1 49)
32	BZ, Sulfonate, 3,5-di-CONH$_2$	SO_3H	$CONH_2$	$CONH_2$	$\Pi_{\text{BZ Sulfonate}}$ + 2$\Pi_{2\ I}$ + $\Pi_{4\ I}$ + 2Π_{CONH_2} 2 25 + 2 21 − 2 98
33	BZ, Sulfonate, 3,5 di-NH$_2$	SO_3H	NH_2	NH_2	$\Pi_{\text{BZ Sulfonate}}$ + 2$\Pi_{2\ I}$ + $\Pi_{4\ I}$ + 2$\Pi_{3\ NH_2}$ 2 25 + 2 21 2(− 1 60)
34	BZ,3 5 di-SO$_2$NH$_2$	COOH	SO_2NH_2	SO_2NH_2	$\Pi_{2\,4\,6\text{ Tri I BZ}}$ + 2$\Pi_{SO_2NH_2}$ 4 08 + 2(− 1 82)
35	BZ, Sulfonate, 3,5 di-SO$_2$NH$_2$	SO_3H	SO_2NH_2	SO_2NH_2	$\Pi_{\text{BZ Sulfonate}}$ + 2$\Pi_{2\ I}$ + $\Pi_{4\ I}$ + 2$\Pi_{SO_2NH_2}$ − 2 25 + 2 21 + 2(− 1 82)
36	BZ,3,5-di-CONHC$_2$H$_4$OH	COOH	$CONHC_2H_4OH$	$CONHC_2H_4OH$	$\Pi_{2\,4\,6\text{ Tri I BZ}}$ + 2$\Pi_{CONHC_2H_4OH}$ 4 08 + 2(1 99)
37	BZ,3,5-di-CONHCH$_2$OH	COOH	$CONHCH_2OH$	$CONHCH_2OH$	$\Pi_{\ 4\,6\text{ Tri I BZ}}$ + 2Π_{CONHCH_2OH} 4 08 + 2(− 2 15)

* BZ = Benzene

The reason for the relation between toxicity and lipid solubility is probably due to the dependence of blood-brain barrier permeability on lipid solubility, as well as on known relations of lipid solubility to direct neuronal action (CRONE, RAPOPORT) Even small amounts of contrast agents will be neurotoxic, since they can modify the

Table 5 (*cont.*)

g P_{EA}	Log P*	Log 1/LD_{50} (predicted)	LD_{50} mM/kg (predicted)
2.60	−1.32	−1.60	4.00×10^{1}
2.50	−1.42	−1.66	4.57×10^{1}
1.96	−1.96	−2.05	1.12×10^{2}
1.30	−2.63	−2.57	3.72×10^{2}
1.10	−2.82	−2.73	5.37×10^{2}
1.08	−3.02	−2.91	8.13×10^{2}
0.86	−3.24	−3.10	1.26×10^{3}
0.44	−3.48	−3.32	2.09×10^{3}
0.42	−3.68	−3.57	3.24×10^{3}
0.1	−3.82	−3.64	4.37×10^{3}
−0.22	4.14	−3.96	9.12×10^{3}

electrical and metabolic properties of neurons within the central nervous system (HOPPE 1959, ALMÉN 1971, LAMPE et coll 1970, BARKER & LEVITAN 1971, LEVITAN & BARKER 1972)

The present analysis provides a quantitative method for designing iodinated organic

Table 5

Calculation of partition parameters and predicted toxicities in mice for a series of iodo benzoic and iodo-benzenesulfonic acids. Log P_{HA} was calculated by means of the additive-constitutive rule of Eq. 1. Log P^* was taken equal to log P_A for the benzene-sulfonic acids, which are almost completely ionized at pH 7.4. Log P^* was calculated from P_{HA}, $pK_a = 3.0$ and pH = 7.4 by means of Eq. 3 for the benzoic acids, letting $P_A = 10^{-4.1}P_{HA}$. Values of toxicity, $1/LD_{50}$, were estimated by means of Eq. 4 from values of log P^*, and are plotted as a function of P^* in Fig. 1.

Compound Name	Substituents (ring: R_1; I, I; R_3, R_5; I) R_1	R_3	R_5	Calculation of Log P_{HA}
27 Metrizoate (Isopaque)	COOH	$N(CH_3)COCH_3$	$NHCOCH_3$	$\Pi_{2,4,6\ Tri\ I\ BZ}$* $+ \Pi_{NHCOCH_3} + \Pi_{N(CH_3)COCH_3}$ 4 08 − 0 79 − 0 69
28 Diatrizoate (Hypaque)	COOH	$NHCOCH_3$	$NHCOCH_3$	$\Pi_{2,4,6\ Tri\ I\ BZ} + 2\Pi_{NHCOCH_3}$ 4 08 + 2(0 79)
29 Iothalamate (Conray)	COOH	$CONHCH_3$	$NHCOCH_3$	$\Pi_{2,4,6\ Tri\ I\ BZ} + \Pi_{CONH_2} + \Pi_{CH_3\ on\ N} + \Pi_{NHCOCH_3}$ 4 08 − 1 49 + 0 16 − 0 79
30 Ioxitalamate (Vasobrix)	COOH	$CONHCH_2CH_2OH$	$NHCOCH_3$	$\Pi_{2,4,6\ Tri\ I\ BZ} + \Pi_{CONHCH_3} + \Pi_{CH_2OH} + \Pi_{NHCOCH_3}$ 4 08 − 1 33 − 0 66 0 79
31 BZ,3,5-di $CONH_2$	COOH	$CONH_2$	$CONH_2$	$\Pi_{2,4,6\ Tri\ I\ BZ} + 2\Pi_{CONH_2}$ 4 08 + 2(− 1 49)
32 BZ, Sulfonate, 3,5-di $CONH_2$	SO_3H	$CONH_2$	$CONH_2$	$\Pi_{BZ\ Sulfonate} + 2\Pi_{2\ I} + \Pi_{4\ I} + 2\Pi_{CONH_2}$ − 2 25 + 2 21 − 2 98
33 BZ, Sulfonate, 3,5-di-NH_2	SO_3H	NH_2	NH_2	$\Pi_{BZ\ Sulfonate} + 2\Pi_{2\ I} + \Pi_{4\ I} + 2\Pi_{3\ NH_2}$ 2 25 + 2 21 + 2(− 1 60)
34 BZ 3,5 di-SO_2NH_2	COOH	SO_2NH_2	SO_2NH_2	$\Pi_{2,4,6\ Tri\ I\ BZ} + 2\Pi_{SO_2NH_2}$ 4 08 + 2(1 82)
35 BZ, Sulfonate, 3,5-di-SO_2NH_2	SO_3H	SO_2NH_2	SO_2NH_2	$\Pi_{BZ\ Sulfonate} + 2\Pi_{2\ I} + \Pi_{4\ I} + 2\Pi_{SO_2NH_2}$ 2 25 + 2 21 + 2(− 1 82)
36 BZ,3,5-di-$CONHC_2H_4OH$	COOH	$CONHC_2H_4OH$	$CONHC_2H_4OH$	$\Pi_{2,4,6\ Tri\ I\ BZ} + 2\Pi_{CONHC_2H_4OH}$ 4 08 + 2(− 1 99)
37 BZ,3 5-di-$CONHCH_2OH$	COOH	$CONHCH_2OH$	$CONHCH_2OH$	$\Pi_{2,4,6\ Tri\ I\ BZ} + 2\Pi_{CONHCH_2OH}$ 4 08 + 2(− 2 15)

* BZ = Benzene

The reason for the relation between toxicity and lipid solubility is probably due to the dependence of blood-brain barrier permeability on lipid solubility, as well as on known relations of lipid solubility to direct neuronal action (CRONE, RAPOPORT). Even small amounts of contrast agents will be neurotoxic, since they can modify the

ZUSAMMENFASSUNG

Die Toxizität von Kontrastmittel, d h ionisierter Jodobenzoic-Säuren und deren Derivate, ist hochgradig zur Fett Loslichkeit korreliert, wie sie durch den Oktanol/Wasser Partial Koeffizienten gemessen wurde Es wurden neue Kontrastmittel entwickelt mit niedrigerer Fettloslichkeit als die allgemein verwendeten, wobei die additiv-konstitutive Natur des Partial Koeffizienten einer organischen Substanz berucksichtigt wurde Falls diese Kontrastmittel chemisch stabil sind, sollten sie auch weniger toxisch sein Es bleibt zu testen, ob die Relation zwischen klinischer Toxizität und Fett-Löslichkeit auch fur nicht ionisierte Kontrastmittel gultig ist

RÉSUMÉ

La toxicite des moyens de contraste qui sont des acides iodobenzoïques ou leurs dérivés est fortement corrélee avec la solubilité lipidique mesurée par le coefficient de partition octanol/eau De nouveaux moyens de contraste ayant une solubilité lipidique inférieure à celle des moyens de contraste d'usage courant ont été créés en tenant compte de la nature additive-constitutive du coefficient de partition d'un composé organique Si ces moyens de contraste sont chimiquement stables ils devraient être aussi moins toxiques Il reste à expérimenter si la relation entre la toxicité clinique et la solubilite lipidique s'applique aussi aux moyens de contraste non ionises

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Table 6

Calculation to estimate partition coefficient of glucoseamide of metrizoic acid

Substituent	π
Benzamide	+0.64[a]
2-I	+1.20[b]
6-I − 2-I	+1.20[b]
4 I	+1.90[b]
$NHCOCH_3$	−0.97[c]
$N(CH_3)COCH_3$	−0.87[d]
Glucose	−3.29[e]
	−0.19 − log P

[a] From HANSCH et coll (1973 a)
[b] These values were estimated to be 0.7 greater than those reported for benzoic acid substitution on the basis of the difference found between π values reported for the halides F, Cl and Br when used in the benzoic acid system and the benzamide system (FUJITA et coll, HANSCH et coll 1973 a)
[c] From benzene system (HANSCH et coll 1973 b)
[d] From HANSCH et coll (1972, 1973 b)
[e] From LEO et coll

acids with low partition coefficients which satisfy the criteria for an ideal agent without significant compromise, and it suggests several compounds which are worthy of clinical evaluation By focusing attention on minimizing the partition parameter as a critical design parameter, many of the criteria can be accomodated It is hoped that octanol/water partition coefficients and pK_a will be measured routinely for contrast agents, and be experimentally related to toxicity Calculation of the partition parameters from the additive-constitutive rules is necessarily inexact

Acknowledgements

This work was supported in part by a grant from the National Science Foundation (GB-43141) and the computer time was supported in part through the facilities of the Computer Science Center of the University of Maryland

SUMMARY

Toxicity of contrast media that are ionized iodobenzoic acids or their derivatives is highly correlated with lipid solubility, as measured by the octanol/water partition coefficient New contrast media have been designed with lower lipid solubility than media in current use, taking into account the additive constitutive nature of the partition coefficient of an organic compound If these contrast media are chemically stable, they should also be less toxic It remains to be tested whether the relation between clinical toxicity and lipid solubility applies to non-ionized contrast media as well

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR HERBERT L. ABRAMS), HARVARD MEDICAL SCHOOL, BOSTON, MASS 021 15 U S A

EFFECT OF EPINEPHRINE ON THE CONTRACTIONS IN THE NORMAL RENAL PELVIS IN MAN

A cineradiographic investigation

L BJÖRK

During angiography of the kidneys, it was observed that intra-arterial epinephrine injections produce not only arterial constriction (ABRAMS et coll 1962, ABRAMS 1964), but also considerable contraction changes in the renal pelvis This was thought to offer a method for enhancing the diagnostic value of cineradiography of the upper urinary tract Therefore, the effect of epinephrine injections on the contractions of the normal renal pelvis was evaluated in a group of patients to establish a baseline for later examinations of patients with renal disease

Material and Methods

Cinematography was performed in 22 patients, examined for possible renal tumours or with hypertension All had normal renal function and no evidence of urinary tract infection, as well as normal arteries, kidney and renal pelvis on that side on which cinematography was performed The ages ranged from 26 to 69 years, 12

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sidered for angiography, the procedure would involve catheterization of the renal artery for injection of the epinephrine and contrast medium This invasive procedure carries obvious risks Compared to other invasive methods (such as retrograde pyelography), the risk of infection of the urinary tract is eliminated and anesthesia is avoided in male patients

The mechanism of changing the contractions of the renal pelvis after epinephrine injection is unclear Most likely there is a direct effect on the muscle of the pelvis leading to increase in frequency and magnitude of contractions Other possible mechanisms are the reduction of blood flow to the kidneys and decrease of urine production following epinephrine injection These effects would decrease distension of the renal pelvis and thus might lead to more complete contractions This hypothesis does not explain the increase in frequency of contractions, however

The absence of changed contractions after epinephrine in 2 subjects is unexplained In one of these patients the epinephrine injection was repeated with a similar result These 2 patients may have had a decreased sensitivity to the drug or they may in fact have had some abnormality of the renal pelvis leading to an inadequate response to epinephrine On careful examination of the history as well as clinical, radiographic and laboratory findings, no obvious explanations for the absence of response to epinephrine were found for either patient

SUMMARY

In 22 normal subjects a marked increase in the frequency and degree of contractions of the renal pelvis occurred after injections of 6 to 10 μg of epinephrine into the renal artery Such injections may be used to increase the diagnostic value of cineradiography of the renal pelvis

ZUSAMMENFASSUNG

Ein markanter Anstieg in der Frequenz und dem Grad der Kontraktionen des Nierenbeckens wurde bei 22 normalen Fallen nach Injektion von 6 bis 10 μg Epinephrin in die Nierenarterie beobachtet Der diagnostische Wert der Rontgenkinematographie des Nierenbeckens kann dadurch erhoht werden

RÉSUME

Chez 22 sujets normaux des injections de 6 a 10 μg d epinephrine dans l artere rénale ont entrainé une nette augmentation de la fréquence et de l intensite des contractions du bassinet rénal Ces injections peuvent etre utilisees pour augmenter la valeur diagnostique de la cinéradiographie du bassinet rénal

were women and 10 men None of the patients received drugs which could have affected contractions of the pelvis The patients were not water-depleted to ensure good diuresis

Abdominal aortography and selective nephroangiography were performed in all patients After injection of the contrast medium, the patients were rotated 360° to avoid any layering of the medium in the renal pelvis Cineradiography of the contractions of the pelvis was performed using the technique previously described (BJÖRK & NYLEN 1972) There was generally excellent filling of the pelvis

Thereafter 6 to 10 μg of epinephrine was injected into the renal artery, and selective nephroangiography was repeated as part of the routine angiographic examination Following this a second cineradiography of the renal pelvis now in its contracted state was carried out

The cine films were analysed for the type of renal pelvis, the frequency of contractions, the starting point of the contractions, and the degree of contraction in the various parts of the upper urinary tract The findings before and after infusion of epinephrine were compared for each subject

Results

The contractions of the upper urinary tract without epinephrine injection did not differ from findings previously reported (BJÖRK & NYLEN) The number of contractions, the completeness and the starting point of contractions varied widely but the pattern in the individual subject remained constant

Following epinephrine injection the number of contractions per minute increased in most subjects, in 8 the number per minute doubled, in 7 the contractions became three times more frequent, and in 4 four times more frequent than before the injections of epinephrine In 1 subject only minute changes in the frequency of contractions occurred and in 2 subjects none at all The starting point did not change in any subject following epinephrine injection The degree increased in all subjects except the 2 in whom no changes in the rate occurred In 4 subjects this effect was very marked with complete emptying of the renal pelvis in the others the effect was more moderate

Discussion

Injection of epinephrine into the renal artery considerably increased the frequency and degree of contractions of the renal pelvis in most subjects This procedure may be useful as a test for evaluating local involvement of the renal pelvis or changes of its contractions It also facilitates evaluation of localized motility of the renal pelvis In patients examined by nephroangiography, epinephrine may be injected with no extra discomfort and very little risk for the patient In patients not con

sidered for angiography, the procedure would involve catheterization of the renal artery for injection of the epinephrine and contrast medium This invasive procedure carries obvious risks Compared to other invasive methods (such as retrograde pyelography), the risk of infection of the urinary tract is eliminated and anesthesia is avoided in male patients

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SUMMARY

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ZUSAMMENFASSUNG

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PERITONEOGRAPHY IN SPIGELIAN HERNIAS

T SVAHN and L SPANGEN

Spigelian hernia of the abdominal wall is infrequent The diagnosis rests on clinical examination although it is true that large intramural hernias of this type containing intestinal loops, may be revealed on roentgen examination of the colon (BRYK 1967, ARIDA et coll 1970, OEN 1971) In addition, HODES & PLISKIN (1968) reported on one patient in whom conventional films of the abdomen were contributory to the diagnosis ARNER & FERNSTRÖM (1970) have suggested that peritoneography and herniography might be helpful in diagnosing this type of interstitial hernia but there is not actual experience available Therefore, peritoneography was performed in a series of patients with Spigelian hernias and the results will now be reported

Anatomy The straight muscle of abdomen forms the medial part of the ventral abdominal wall It is surrounded by the rectus sheath, which is composed of the medial extension of the aponeuroses of the three lateral abdominal muscles external and internal oblique muscles and the transverse muscle (*Fig 1*)

Laterally at the transition of the transverse muscle to its aponeurosis a curved fibrous structure is present, the semilunar line or *linea Spigelii* The aponeurosis, which extends from the semilunar line to the lateral edge of the rectus muscle is named fascia or zona Spigelii When this fascia is partly defective, a hernia may develop (Fig 2) The aponeurosis of the transverse muscle, being part of the Spigelian fascia, firmly adheres to the internal oblique muscle and its aponeurotic bundles A

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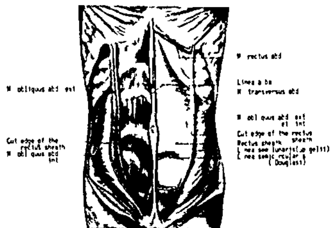


Fig 1



Fig 2

Fig 1 Anatomy of ventral abdominal wall following removal of right external oblique muscle, right anterior part of rectus sheath, and left rectus and internal muscles

Fig 2 Ventral view of a Spigelian hernia (⟶) explored at surgery Aponeurosis of external oblique muscle is divided Metal clamp at lateral edge of the straight muscle of abdomen

hernial sac therefore almost invariably penetrates both these layers (Fig 3) The width of the neck of a Spigelian hernia usually varies between 0 5 and 2 0 cm The confines of the neck are well demarcated but may be difficult to explore at surgery

A small hernia may consist of a protrusion of the preperitoneal fat through the Spigelian fascia, a condition similar to that present in a fatty hernia of the linea alba An expanding sac of a larger hernia will dissect between the internal and external oblique muscles forming an intramural or interstitial hernia, usually located at a level below the umbilicus

Clinical findings In contrast to large, palpable Spigelian hernias, readily discovered on physical examination, small hernias are easily overlooked clinically if due attention is not paid to the presence of a circumscribed area of tenderness in the abdominal wall Otherwise the clinical symptoms and signs generally are those of complaints of pain with or without a soft tissue mass or only the latter In the majority of the patients, especially in early stages of a Spigelian hernia, pain is uncharacteristic and difficult to localize Hence, the condition is liable to be mistaken for a different intraabdominal disease

Materials and Methods Twelve patients, aged 15 to 47 years, who all underwent surgery for a Spigelian hernia, became subjects to preoperative peritoneography This was especially designed for detecting lesions in the anterior abdominal wall Following needle puncture of the wall opposite to the area of the expected hernia, 1 000 ml carbon dioxide and 50 to 100 ml contrast medium (Isopaque Cerebral, Nyegaard, Norway) were injected into the peritoneal cavity under fluoroscopy The technique used was in most respects similar to that described by GULLMO (1973) for the

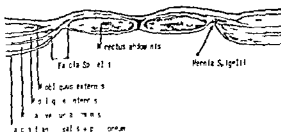


Fig 3 Transverse section of abdominal wall caudal to semicircular line of Douglas demonstrating a small Spigelian hernia

examination of femoral and inguinal hernia The large amount of gas injected served the purpose to distend the abdomen in order to obtain a satisfactory delineation of the inner aspects of the abdominal wall free of gas-containing intestinal loops Following indication on the abdominal wall of the assumed site of the hernia, the wall was examined in a tangential projection with a horizontal beam direction the patient being placed in supine and prone positions Exposures were made both in rest and with the patients straining

Results

No Spigelian hernia was diagnosed at the roentgen examination Subsequent surgery in all 12 patients revealed a small herniation of preperitoneal fat and peritoneum within ruptured fibers of the aponeurosis of the transverse and internal oblique muscles and covered by the intact external aponeurosis The intestines were uninvolved The thickness of the very edge of the hernial neck did not exceed 0 5 cm

Incidentally several small and clinically insignificant umbilical hernias of less than 0 5 cm in diameter were revealed at the roentgen examination and confirmed at surgery

Discussion

The prevalence of Spigelian hernias is generally regarded low, less than 300 cases having been described in the literature Peritoneography has previously not been used to any large extent in the case of Spigelian hernias and this diagnosis seems never to have been established by peritoneography or herniography Observations made in the present series indicate that these procedures should not be applied in early stages of Spigelian hernias The pathology of minor lesions not involving the intestines is such as not to allow of a radiologic detection In view of this fact peritoneography and herniography should be discarded for the diagnosis of minor Spigelian hernias

SUMMARY

Twelve patients with a minor Spigelian hernia not involving the intestines have been examined by combined peritoneography and herniography The particular pathology of this hernia does not lend itself to be detected by these procedures

ZUSAMMENFASSUNG

Zwolf Patienten mit einer kleinen Spieghelschen Hernie, die nicht den Dunndarm umfasste, wurden mittels kombinierter Peritoneographie und Herniographie untersucht Die besondere Pathologie dieser Hernie kann nicht durch diese Verfahren dargestellt werden

RÉSUMÉ

Douze malades atteints d'une petite hernie de Spiegel ne comportant pas de hernie des intestins ont été examinés par péritonéographie et par herniographie L'anatomie pathologique particulière de cette hernie ne se prête pas au diagnostic par ces méthodes

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PHOTOGRAPHIC SUBTRACTION

II Technical aspects and method

CH HARDSTEDT, B RUNDELIUS and U WELANDER

The object of subtraction (ZIEDSES DES PLANTES 1934, 1961) is to depict the diagnostic information in a roentgen image without the interference of information with no diagnostic significance, image noise (HÅRDSTEDT & WELANDER 1975)

The theory of the subtraction image, and the criteria to be applied for attaining optimum subtraction were presented in part I The aim of this second part is to describe the technical aspects of the subtraction procedure and present a simple method for use in routine work

To achieve optimum subtraction the original image must have satisfactory phototechnical properties, which depend on a number of factors Only those which are of significance for the procedure of subtraction are discussed in this report

Technical aspects

The masking film The first step is to produce a mask meeting the following requirements The masking film should have a γ-value of 1 0 (Fig 1) All details to be subtracted should be exposed within the straight part of the characteristic film

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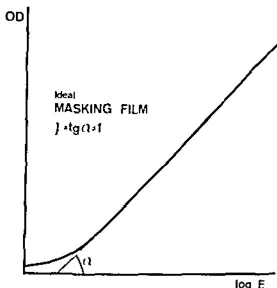


Fig. 1. Contrast is indicated by the slope of the straight part of the characteristic curve, $\gamma = \mathrm{tg}\,\alpha$

curve, the lowest density of details to be subtracted should exceed 0.25 above fog level.

The contrast of the masking film is the most critical factor in achieving a proper subtraction image. It is influenced by a number of variables, important among these is the characteristic curve of the film reflected in its γ-value, which will vary with the type of developer used, the developing time and the temperature (Fig. 2). Some photographic emulsions used for graphic purposes furthermore vary in sensitivity when exposed to light of different colors (Fig. 3). A high color temperature will produce a low γ-value while a low one is associated with a high γ value. Exposure with filtered light similarly will change the γ-value, blue light gives the lowest, red light the highest value.

A film with a γ-value as close to 1.0 as possible should be chosen for the mask. At manual development the developing time and temperature suitable to an optimum γ-value should be ascertained by test. However, for routine purposes at a roentgen unit it may be convenient to develop the masking film in a processing machine, the developing time and temperature being held constant. Advantage is then taken of the property of some graphic films to respond with variable contrast when exposed to light of different colors. If the contrast in the masking film is too high the color temperature of the light can be raised to compensate for this, the masking film should be exposed in blue light. Conversely, if the contrast is too low the color temperature should be lowered by using yellow light.

As a consequence of the varied response to light of different color temperatures, the γ value of the masking film *will be influenced by the color of the original film*. A blue and white film, such as the Medichrome film (DE BELDER & BOLLEN 1972), transmits, even at high densities, the greater part of the short wave lengths, i.e. blue light, while absorption is considerable for the light of the longer wave lengths. This

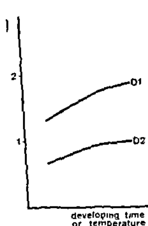


Fig 2

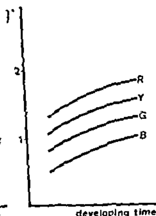


Fig 3

Fig 2 Developers D 1 and D 2 give different values for γ The γ value also depends on development time and temperature

Fig 3 Variation of γ of some graphic emulsions exposed to light of different color temperatures Blue (B), green (G) yellow (Y) and red (R) light gives successively higher γ-values

means that a Medichrome film will act as a filter which changes the color temperature of the exposing light This implies that a blue and white original film alters the γ-value of the print It will be slightly lower when compared to that following printing from a black and white original film which uniformly absorbs light from the whole spectrum of wave lengths This means that with blue and white original films the color temperature of the light should be lowered when printing the mask

The diffusion of light produced at its passage through emulsion and the base material of the film results in a loss of resolution In order to reduce this factor as much as possible the mask should be exposed on a fine-grained, single coated film of a neutral and dimension-stable material and which tightly adheres to the original film These requirements for a masking film are met by GO 23p (Agfa Gevaert) It has a γ-value which for all practical purposes varies between 0 6 and 1 6 depending on the developing time and on the color temperature of the light source

The subtraction film The subtraction image should meet the following requirements It should be a positive The background of subtracted details must have a homogeneous density, and be visible in its entirety The background should be exposed to provide for a density of about 1 0 The contrast in the subtraction image should be as high as possible and still allow retention of a homogeneous density in the background of subtracted structures The subtraction image should reproduce details in the original film corresponding to a resolution of at least 3 lines/mm with retained or increased contrast

With a standard method of development these criteria can be met if a film be chosen which gives a suitable γ-value on exposure with standard light, as is the case with N 33p (Agfa Gevaert), which has a blue sensitive emulsion It is fine-grained and single coated and requires a 3 5 minute developing process When the

Table

γ-values obtained on exposure of G0 23p with an ordinary 25 W electric light bulb through a series of standard filters, all values rounded off to the nearest higher or lower 1/10th (90s development process, temperature 32°C, developer G 138, Agfa-Gevaert)

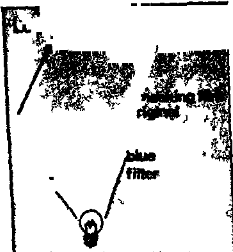
Filter	γ-value Black and white original film	γ-value Blue and white original film (Medichrome), OD 1.25
U 449	0.6	0.6
U 472	0.8	0.8
L 453	1.0	0.9
L 477	1.1	1.0
L 489	1.2	1.1
L 510	1.3	1.2
L 519	1.4	1.2
Unfiltered light, 25 W light bulb	0.9	0.8

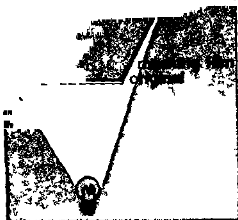
printing is done from black and white originals the γ-value of G0 23p can be raised by means of exposure in yellow light, thus, meeting the requirements of a suitable film.

Contact printing with filters. Since the γ-value can be varied with the aid of the color temperature of the exposing light, a printer of standard type should be fitted with a filter between the exposing light and the film (Fig. 4), photographic standard filters will cover a fairly wide range of γ-values (Table). The table lists a series of two blue filters (U 449, U 472, Agfa-Gevaert) and five yellow filters (L 453, L 477, L 489, L 510, L 519, Agfa-Gevaert), with aid of which the γ-value of the masking film (G0 23p) can be varied between 0.6 and 1.4, when a black and white original is used, and between 0.6 and 1.2 with a blue and white original.

When preparing for optimum contrast in the masking film, the γ-value resulting from exposure with the standard light of the printer is tested first. On the basis of the value obtained, the appropriate filter which should compensate for too high or too low a γ-value is then selected. For a black and white original, the γ-value is adjusted to 1.0. When a blue and white film is concerned the true γ-value of the mask will have to exceed 1.0 owing to the fact that the original film will act as a color filter. The exposure should result in an effective γ-value of the masking film of 1.0.

Continuous variation of the γ-value is achieved by providing the contact printer with three lamps. The light from two of them is filtered, one with a blue and the other with a yellow filter. The blue light gives the lowest γ-value, the yellow light the highest, and the unfiltered light an intermediate value. Any change in the γ-value can be obtained by properly combining unfiltered light with either blue or yellow light, if a film receives, for instance, 50 per cent of the exposure needed for a given





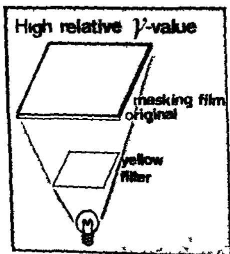


Fig. 4 Schematic demonstration of contact printing with filters

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Continuous variation of the γ-value is achieved by providing the contact printer with three lamps The light from two of them is filtered, one with a blue and the other with a yellow filter The blue light gives the lowest γ-value, the yellow light the highest, and the unfiltered light an intermediate value Any change in the γ-value can be obtained by properly combining unfiltered light with either blue or yellow light, if a film receives, for instance, 50 per cent of the exposure needed for a given

density with unfiltered light and 50 per cent with yellow light, a γ-value will result which is intermediate between the values obtained by each light source

In practice the γ-value is tested by separate exposures from three lamps On the basis of the γ-values obtained the proportions of the mixture of blue, yellow and unfiltered light intended to result in a $\gamma = 1\ 0$ are then determined

The subtraction method

The mask The original film is placed in the printer The emulsion side of the masking film should face the original, and moderate pressure be applied so that the films make good contact The masking film is exposed in suitable filtered light for a sufficient length of time to ensure that the average density of the structural details in the original to be subtracted have a lowest density of 0 25 above fog and an average density of about 1 0 The masking film is developed in an ordinary processing machine

Superimposition The original and the mask are superimposed, with the emulsion side of the mask facing the original After careful adjustment they are fixed together with tape

The subtraction image The block with the original and the mask are placed in the printer with the mask towards the exposing light The emulsion side of the subtraction film should face the original film, and moderate pressure be applied so as to obtain satisfactory contact between the films The subtraction film is exposed for a sufficient length of time to give the background of subtracted structures a density of about 1 0, with black and white originals, N 33p is exposed with unfiltered light, or G0 23p with an appropriate yellow filter, with a blue and white original, N 33p is exposed with unfiltered light

Discussion

The critical factor in achieving an optimum subtraction is the process of preparing a mask that as completely as possible will level the image noise to be subtracted, such a mask must have a γ-value of 1 0 With automatic developing of the film, it is impracticable to change the development time, which is usually the factor varied in order to optimize the γ value However, a masking film providing for an improved subtraction image may be produced by making use of the capacity of some graphic emulsions to respond with different γ-values to exposure light of variable color temperatures This method needs usage of filters Once the optimum exposure conditions including the appropriate filtration of light, have been determined by test, the procedure can be carried out in exact accordance with the generally applied technique

The subtraction method described in this report has been adapted to suit both black and white original films and blue and white Medichrome originals As a rule,

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KINEMATIC ANALYSIS OF EXPERIMENTALLY PROVOKED SCOLIOSIS IN PIGS WITH ROENTGEN STEREOPHOTOGRAMMETRY

T OLIN, T H OLSSON, G SELVIK and S WILLNER

Surgical treatment of different kinds of lesions of the human spine has become more common, necessitating an accurate method to evaluate small movements between adjacent vertebrae Such a method has been developed in Lund (SELVIK 1974) and as a methodologic investigation the development of experimentally provoked scoliosis has been followed in four pigs

The various methods existing to measure the movements of the human vertebral column have been reviewed by ANDERSSON & EKSTRÖM (1941) and WHITE (1969) Many kinds of mechanical devices have been used MEYER (1873) obtained a precision for side-bending of 0 02° with such a device utilizing pins inserted into the vertebrae GREGERSEN & LUCAS (1967) put Steinmann pins into the spinous processes of 7 volunteers They measured the movements including rotational ones, even during walking A similar mechanical method on anatomic specimens was used by ROLANDER (1966) in order to measure the movement after fixation of the posterior vertebral elements A three-dimensional approach was made by REINER & WERNDORFF (1905)

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if subtraction be limited to black and white images the same type of film, G0 23p for instance, can be used for both mask and subtraction image, provided that color sensitivity be utilized for varying the γ-value When producing a mask, optimized to $\gamma = 1.0$, the film is exposed to light of a color high temperature For the exposure of the subtraction film, light with a low color temperature is used instead and the subtraction image will attain a higher γ-value For subtraction with Medichrome film, the same technique can be used to simplify the procedure, but a single coated film would be needed

SUMMARY

Technical aspects of photographic subtraction of original films in black and white and blue and white (Medichrome) under standard development conditions available in any roentgen unit are described The adjustment necessary to control the γ value of the masking film takes advantage of the capacity of some graphic films to respond with different γ-values on variation of the color of the exposure light

ZUSAMMENFASSUNG

Die technischen Aspekte der photographischen Subtraktion von Originalfilmen in schwarz weiss und blau weiss (Medichrom) unter gewohnlichen Entwicklungsbedingungen, wie sie in jeder Rontgenabteilung vorhanden sind, werden beschrieben Die Anordnung *die notwendig ist um den γ-Wert des maskierenden Films zu kontrollieren*, zieht Vorteil aus der Kapazitat einiger graphischer Filme, mit verschiedenen γ Werten auf Änderungen der Farbe des Expositionslichtes zu reagieren

RÉSUME

Les auteurs décrivent les aspects techniques de la soustraction photographique de films originaux en noir et blanc et en bleu et blanc (Médichrome) dans les conditions habituelles de développement existant dans tous les services de radiologie L'ajustement nécessaire pour modifier le gamma du film masque bénéficie de la propriété de certains films graphiques dont le gamma varie en fonction de la couleur de la lumiere d exposition

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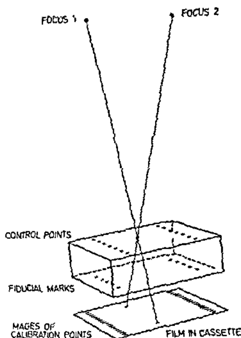


Fig 1 The radiation beams from the two tubes FFD 120 cm, distance between the foci about 70 cm Between film and table an airgap of 20 cm.

The method requires at least three reference points in each vertebra Tantalum spheres with a diameter of 0 5 or 0 8 mm were used Tantalum was chosen because of its high atomic number (73) and because of its inertness (BJÖRK 1968, MCFADDEN 1969)

We have used the special instrument designed by ARONSON et coll (1974) for insertion of the tantalum indicators into the vertebrae Indicators were introduced into the posterior elements of each vertebra to be examined One indicator was positioned in the lateral part of the lamina or in an articular process and one at the base of the spinous process.

Exposures were made on one film with two standard tubes simultaneously (Fig 1) Medium speed intensifying screens and foci of 0 6 mm were used The FFD was 120 cm and the distance between the two foci about 70 cm Between the objects and the film there was an airgap of 20 cm in order to reduce the scattered radiation. The relationships between the film, tube foci, and the laboratory reference system were determined each time with the use of a calibration cage containing markers defining the laboratory reference system The markers are located at the two ends of the cage and a space about 40 cm long is shielded with a lead sheet in the middle of the cage The cage is exposed, then shields are applied over the exposed areas and a second exposure is made with the animal positioned in the center

The films are measured in an Autograph (A 8, Wild, Heerbrugg) where the drawing table is modified in order to make it possible to transmit the image via a closed

They made a cube with three glass walls. A specimen with steel pins inserted into the vertebral bodies was enclosed within the cube and examined in different positions. By using orthogonal parallel projections of the tips of the pins on the glass walls of the cube and by using descriptive geometry on the projection-figures they were able to obtain a three-dimensional image of the movements between adjacent verte brae. Two-dimensional measurements on roentgenograms have been carried out by FERGUSON (1930), BAKKE et coll. (1931), DITTMAR (1931), ELWARD (1939), COBB (1948), TANZ (1953), AHO et coll. (1955) and SCHALIMTZEK (1958). With the aid of EDHOLM's 'instrument for measuring angles from roentgenograms' (1966), LINDAHL & MOVIN (1968) were able to calculate the 'maximum scoliotic angle' mathematically.

A method to evaluate rotation within the spine by means of the relationship between the tip of the spinous process and the vertebral body as demonstrated on an a.p. film was described by COBB (1948). A similar idea using the relationship between the pedicles and the vertebral bodies was proposed by MOE (1958). However, NORDWALL (1973) stated that such methods are influenced by the deformation of the vertebrae in a scoliotic subject.

Roentgen stereophotogrammetry was introduced by LYSELL (1969) to describe the movements within the cervical spine. The same method has been used by WHITE (1969). It is, however, only applicable to specimens and the mathematical model is 'exact only for infinitesimal rotations' (PANJABI & WHITE 1971).

Another roentgen stereophotogrammetric approach to evaluate scoliotic curves has been made by HINDMARSH (1973). He reports a fairly good precision but his method has the disadvantage that the patient has to be placed within a large calibration cage for every exposure. He also fails to measure the rotation about the longitudinal axis with any reasonable accuracy. Despite the fact that measuring movements in the spinal column has been treated by many authors, no accurate clinical method exists.

Material and Methods

The material consisted of four pigs. On the first pig the dorsal ends of five ribs (9–13) were resected on the right side. The second animal had the dorsal ends of the right ribs 11–15 resected and 9–13 were resected in the third animal. An attempt to destroy the neurocentral junctions in three segments (Th 10–Th 12) on the left side was performed in a fourth pig in order to arrest the growth in these growing zones. At the time of operation the pigs were about five weeks old. All were examined once a week over a period of ten weeks. The anaesthesia used for the operations and during the examinations was droperidolum (INN, NFN, Dridol, Leo) and ketaminehydrochloride (NFN, Ketalar, Parke-Davis). The roentgen stereophotogrammetric technique used has been described in detail by SELVIK (1974), only a short review will be given here.

Table 1

The mean errors (e_{rb}) of rigid body fitting for pig I. The errors are given in μm

Days after operation	19	23	30	36	43	50	57	64	71
Th 8	89	146	445	666	734	811	770	620	554
Th 11 Op	162	167	170	210	178	217	229	139	137
Th 14	70	107	110	146	141	151	134	173	193

One of the requirements for the method is that the reference points of each segment are always stable in relation to each other. In other words, the vertebra must behave as a rigid body. To check this requirement the length of the sides of the polygon marked by the tantalum spheres in each vertebra are measured. The angles between these sides are also determined. The polygons are then compared at intervals so that mobile indicators can be excluded.

A parameter, e_{rb}, is defined, which is the root mean square distance (error) between a segment indicator displaced in a rigid body motion compared to its actual motion. For the exact mathematical definition, see SELVIK (1974, p. 117). This mean error of rigid body fitting includes both deviations from the rigid body behaviour and measurement errors. To ascertain the effect of measurement errors four films were reevaluated and this mean error was computed for the four 'motions' between the two evaluations. Each film included eight indicator segments. From the $n = 4 \times 8 = 32$ motions the mean of the error e_{rb} was obtained equal to 39 μm, and the computed standard error for e_{rb} was 16.7 μm. Assuming a Gaussian distribution of the errors e_{rb}, it may thus be said that in a motion with a mean error e_{rb} larger than 80 μm, the motion of the segment indicators is significantly different from a rigid body motion (at the one-sided 1 % level, n = 32 d.f.).

Results

The rotations of the vertebrae in each pig appear graphically in diagrams marked A_r (rotation) and B_r (rotation), and the translations in diagrams labelled A_{tr} (translation) and B_{tr} (translation). The mean errors of rigid-body fitting are given in Tables 1 to 4. Diagrams labelled A illustrate the measured values regarding one vertebra in relation to the most caudal one examined and diagrams labelled B the calculated values for one segment in relation to its subjacent one.

Thus the rotations for each vertebra in each examination are represented by three staples in diagrams A_r and B_r, respectively, where the first staple indicates the rotations about the x axis, the second about the y axis and the third about the z-axis.

The scoliosis of the first pig secondary to resection of the dorsal ends of five ribs

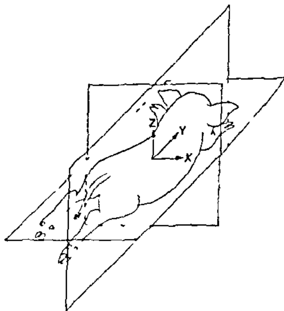


Fig 2 The Cartesian coordinate system determined by the calibration cage at the reference examination

television circuit and to focus the point to be measured on a measuring mark on the television screen

With this instrument the two-dimensional coordinates within the film are determined for the reference points in the calibration cage and in the vertebrae By automatic data processing in a Univac 1108 computer it is possible to determine the coordinates of the indicators in the vertebrae The coordinates are given in the laboratory reference system, a Cartesian coordinate system bound to the calibration cage The motion within a certain time interval of a particular vertebra relative to another may be determined by utilizing another computer program providing that both vertebrae contain at least three indicators and that the vertebrae constitute two rigid bodies

The movement of one vertebra in relation to another is described by the three rotational (Eulerian) angles about the three coordinate axes and the translations along these axes of one particular point within the vertebra In this way six values for the motion as a whole are obtained and thus the six degrees of freedom of a rigid body are determined

The three axes have directions identical to those in the coordinate system of the calibration cage, as these axes are placed during the reference examination The calibration cage should therefore always be placed in such a manner that its coordinate axes coincide as far as possible with the axes of the body examined If these requirements are fulfilled, the x-axis of the cage approximates a transverse axis, the y-axis a longitudinal axis and the z-axis a sagittal axis (Fig 2) The particular point, for which the translations of a vertebra are given, is the center of gravity for the indicators in the vertebra This center of gravity is determined, giving equal weight to each ball Thus a well defined point is obtained which is situated near the median plane providing that the tantalum reference points are symmetrically placed



Fig 3 The first pig when the right convex scoliosis and the kyphosis were at their maxima.

(9–13) on the right side (Fig. 3) is described by means of only three segments, namely the segments caudal and cranial to the five operated ones and the third operated segment In the other segments there were mobile indicators In three segments the indicators, however, behaved according to the rigid body model with reasonably good accuracy (Table 1), where the mean errors of rigid-body fitting for this pig are given The first examination was owing to technical reasons, not made until nine days after the operation but then the gradual development of a kyphoscoliosis was revealed (diagram 1 A_r, Fig 4) The scoliosis is measured as a rotation about the z axis, which is a sagittal axis (striped staples) and this rotation is 29° for Th 8 in relation to Th 14 in the penultimate examination The kyphosis, which is measured as a negative rotation about the x-axis, a transversal axis, amounts to 23° for the same segments at the same time (stippled staples) The kyphosis has developed between Th 8 and Th 11 (diagram 1 B_r, Fig 5, stippled staples) The rotation of the former segment is in other words −26° in relation to the latter while the rotation about the same axis is about +5° for Th 11 in relation to Th 14 i e there is a slight lordosis between the last two segments The filled staples indicate the rotation about the y axis, which may be considered as the longitudinal one It is obvious that there is a negative rotation of Th 11 and a positive one of Th 8 in relation to Th 14 and 11, respectively (diagram 1 B_r, Fig 5) A negative rotation means that the vertebral body is rotated towards the right side of the pig or towards the convex side of the scoliosis Consequently Th 11, which constitutes the vertex of the scoliosis, has rotated against the convexity of the scoliosis and Th 8 has rotated in the opposite

Table 2

The mean errors (e_{rb}) of rigid body fitting for pig 2 The errors are given in μm

Days after operation	12	16	23	29	36	43	50	57	64
Th 9	81	34	59	30	138	96	145	190	155
Th 10	56	19	28	97	27	64	27	46	53
Th 11 Op	116	78	77	54	107	115	117	103	90
Th 12 Op	45	41	70	49	34	64	47	86	75
Th 13 Op	56	33	22	51	25	22	17	79	37
Th 14 Op	52	36	87	28	92	30	23	83	80
Th 15 Op	70	59	70	87	120	101	126	146	162
L 1	62	30	35	62	66	52	62	83	51

Table 3

The mean errors (e_{rb}) of rigid body fitting for pig 3 The errors are given in μm

Days after operation	2	8	15	22	29	36	43	50	58
Th 7	72	369	491	273	259	209	169	290	293
Th 8	176	168	246	258	206	326	373	365	368
Th 9 Op	11	50	88	116	264	312	354	435	500
Th 10 Op	29	15	46	35	35	229	303	324	382
Th 11 Op	27	102	308	352	433	486	532	579	595
Th 12 Op	58	29	61	37	113	95	120	117	148
Th 13 Op	24	20	51	56	76	84	69	97	111
Th 14	33	41	57	110	84	133	183	219	226

Table 4

The mean errors (e_{rb}) of rigid body fitting for pig 4 The errors are given in μm

Days after operation	8	15	22	29	36	43	51	61	68
Th 7	276	464	459	551	725	723	915	1 203	1 435
Th 8	27	37	27	43	42	51	58	61	64
Th 9	25	62	58	54	74	76	103	158	138
Th 10 Op	58	44	47	51	35	73	75	116	139
Th 11 Op	84	48	35	45	70	79	118	179	197
Th 12 Op	40	9	21	33	94	133	148	151	323
Th 13	153	189	258	246	267	224	224	144	164
Th 14	194	150	164	101	109	82	95	163	206

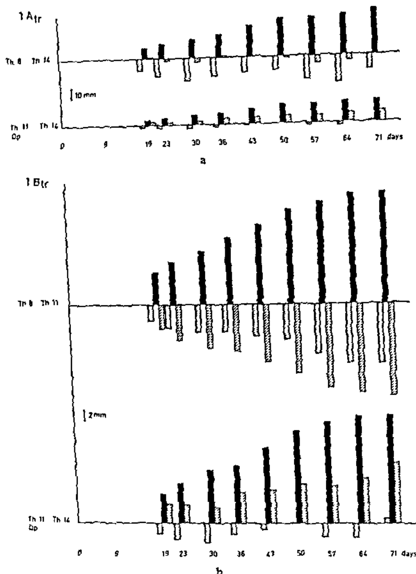


Fig. 6 Diagrams 1 A_{tr} and 1 B_{tr}. The translations along the x-, y- and z-axes (in that order) of the center of gravity of a vertebra relative to another indicated vertebra.

that these errors are as high as 0.8 mm (maximal value) for Th 8, while they are small (not exceeding 0.2 mm) for the two other segments, i.e. the root of the mean of the squared distances from the expected to the actual sites of the indicators is 0.8 mm and 0.2 mm, respectively. Thus, there is a rather important movement between the indicators in Th 8.

Diagrams 2 A_r (Fig. 7), 2 B_r (Fig. 8), 2 A_{tr} (Fig. 9) and 2 B_{tr} (Fig. 10) illustrate

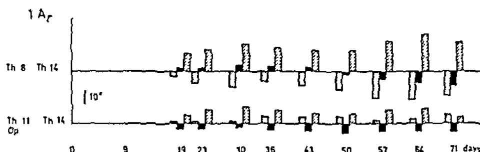


Fig 4 Diagram 1 A_r Each group of staples is a schematic representation of the rotations (Eulerian angles) at a certain time about the x-, y- and z-axes (in that order) for Th 8 and Th 11 in relation to Th 14 compared to their respective relationships during the reference examination 9 days after operation

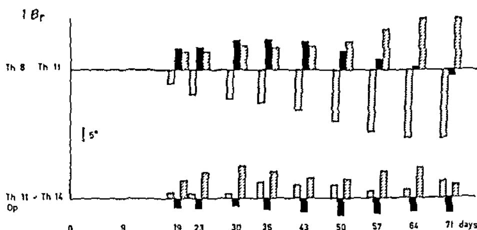


Fig 5 Diagram 1 B_r. Rotation of Th 8 and Th 11 in relation to Th 11 and Th 14, respectively Otherwise the principles are the same as in diagram 1 A_r.

direction in relation to Th 11 These rotations do not appear exactly at the same time as the development of the kyphoscoliosis

In diagrams 1 A_{tr} (Fig 6 a) and 1 B_{tr} (Fig 6 b) the filled staples designate the translations along the y-axis, they demonstrate the longitudinal growth between the vertebrae examined

The stippled staples are the translations of the center of gravity for the indicators along the x-axis Positive values indicate movements towards the right and negative towards the left side of the pig (Fig 2) It should be noted that Th 8 has moved much more in relation to Th 11 than the latter segment has moved in relation to Th 14 (diagram 1 B_{tr}, Fig 6 b), as the scoliotic curve has developed around the axes of Th 11 and the segments cranial to it have moved like a pointer to the left

The striped staples are positive for Th 11 and negative for Th 8 (diagram 1 B_{tr}, Fig 6 b) Positive translations go dorsally and negative ventrally (Fig 2) These observations correspond to the fact that there was a slight lordosis between Th 11 and Th 14 and a kyphosis between Th 8 and Th 11 (diagram 1 B_r, Fig 5)

Table 1 contains the mean errors of rigid body fitting for the first pig It is found

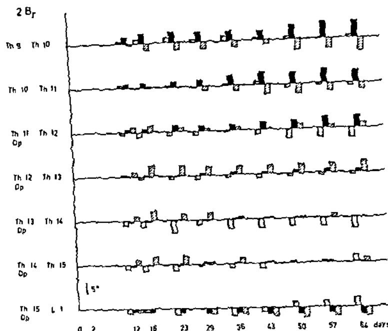


Fig 8 Diagram 2 B_r The rotations (Eulerian angles) about the x-axis (stippled staples) y axis (filled staples) and z-axis (striped staples) for each segment in relation to its subjacent one for each examination compared to the reference examination 2 days after operation.

The vertex of the scoliotic curve (striped staples) is about Th 12 and Th 13 The caudal transitional zone is situated between Th 14 and Th 15 because the rotation about the z axis for Th 15 is negative The cranial transitional zone is at Th 11, and the more cranially located vertebrae constitute a compensatory curve with the convexity to the left

In diagrams 2 A_{tr} (Fig 9) and 2 B_{tr} (Fig 10) the translations for the centers of gravity are given for the second pig The longitudinal growth (filled staples) appears as continuous curves

The stippled staples (diagram 2 A_{tr}, Fig 9) designate the translation along the x axis At the vertex of the scoliosis and cranial to it the translation is at first negative but later becomes positive in relation to L 1 This is explained by the fact that Th 15 is almost neutral during the four first examinations in the frontal plane in relation to L 1 but that a compensatory curve with its convexity to the left is formed later between the former and the latter (diagram 2 B_r, Fig 8)

The striped staples (translations along the z-axis) seem irregular (diagram 2 A_{tr}, Fig 9) but they are also dependent on the rotations between Th 15 and L 1 They are all negative when there is a kyphosis between these vertebrae and they turn to the positive direction when a lordosis gradually develops between these segments (diagram 2 B_r, Fig 8) Table 2 shows that the rigid body model regarding the tantalum

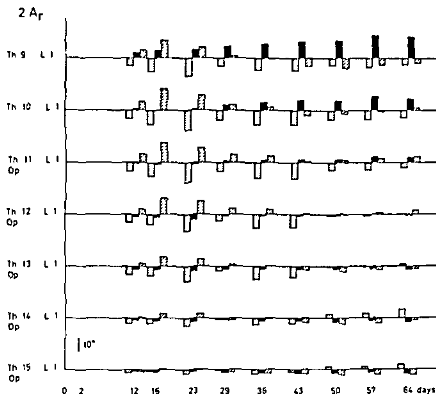


Fig 7 Diagram 2 A_r The rotations for respective segment in relation to L 1 Stippled staples are the rotations about the x axis, filled staples about the y axis and striped staples about the z axis for each examination compared to the reference examination 2 days after operation

the movements within the second pig of each vertebra about and along the x-, y- and z-axes, in relation to the lowermost segment L 1 and in relation to the subjacent one, respectively The second pig was operated upon with resection of the dorsal ends of the right ribs 11–15 The diagrams demonstrate the movements at the five operated segments as well as two above and one below The first examination of this pig was made two days after the operation Owing to technical reasons the second one was not until 10 days later, it is, however, obvious from diagram 2 A_r (Fig 7) that the greatest rotation observed about the z-axis, which corresponds to the curve in the frontal plane, that is the scoliosis, appears 16 days postoperatively and this curve then gradually diminishes (striped staples) In the diagram it may also be seen that the curve about the z-axis is accompanied by a curve about the x-axis (stippled staples) which is negative but of about the same nominal value In other words, the scoliotic curve is combined with a kyphosis The rotation about the y-axis (filled staples) is less prominent but a negative rotation is seen with the maximum at Th 13 and a positive one above Th 11 These rotations approximately correspond to the movement about the longitudinal axis and the negative rotation means that the vertebral body has rotated towards the convex side of the scoliosis and the positive one means the opposite situation for respective segments Diagram 2 B_r (Fig 8) shows the rotation about the above-mentioned axes of each vertebra in relation to its subjacent one

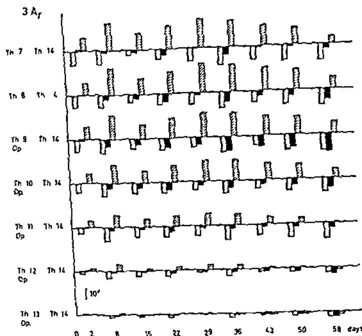


Fig 11 Diagram 3 A_r. Reference examination on the same day as the operation Principles the same as in diagrams 1 A_r and 2 A_r

indicators of this second pig was satisfactory, with mean errors of rigid body fitting always less than 0 2 mm

Diagrams 3 A_r (Fig 11), 3 B_r (Fig 12), 3 A_{tr} (Fig 13) and 3 B_{tr} (Fig 14) represent graphs of the development of the scoliotic curves of the third pig on which the dorsal ends of costae 9–13 were resected In diagram 3 A_r (Fig 11) the rotations of the segments are related to the lowermost one, Th 14, and in diagram 3 B_r (Fig 12) to the subjacent one The vertex of the scoliotic curve that is the maximum of the rotations about the z axis, is situated between Th 10 and Th 11 (diagram 3 B_r) The total curve, i e the rotation of a vertebra in the upper transitional zone in relation to a vertebra in that lower one is 27° when it is at its maximum value (Th 8–Th 14, diagram 3 A_r Fig 11) The kyphosis is smaller and constitutes 16° (Th 7, diagram 3 A_r) *totally* The rotations about the y axis are towards the convex side of the scoliosis regarding Th 9 and Th 10 but towards the opposite side cranial to them (diagram 3 B_r, Fig 12) The kyphosis is most developed between Th 11 and Th 12 while a slight lordosis exists between Th 10 and Th 11 (diagram 3 B_r, Fig 12) This fact is also *demonstrated* in diagram 3 B_{tr} (Fig 14) The striped staples which designate the translations along the z axis, are negative for Th 11 and positive for Th 10, indicating kyphosis in the former and lordosis in the latter segment

The translations along the x axis are to the left caudal to Th 9 and to the right

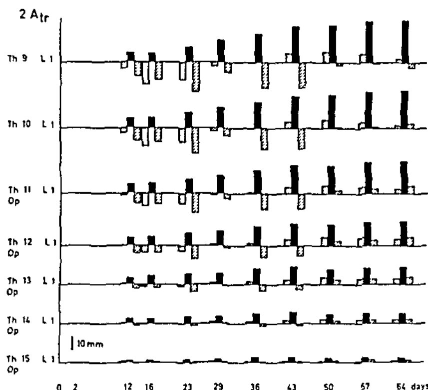


Fig 9 Diagram 2 A_{tr} The translations along the x, y- and z axes (in that order) for each segment in relation to the lowermost one, in which a Cartesian coordinate system was determined by the calibration cage at the reference examination 2 days after operation

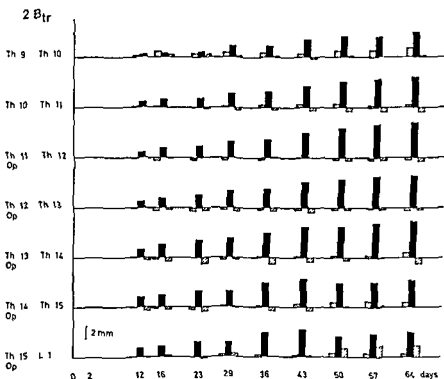


Fig 10 Diagram 2 B_{tr} Translations for each segment in relation to its subjacent one Reference examination 2 days after operation

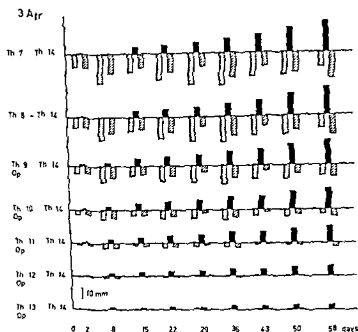


Fig 13 Diagram 3 A_{tr}. Translations along the x , y- and z-axes for each segment in relation to Th 14 For further explanation see legends of previous diagrams

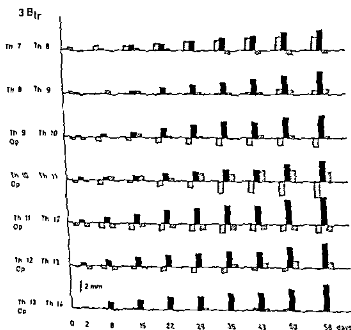


Fig 14 Diagram 3 B_{tr}. Translations for the segments in relation to their subjacent ones See legends of previous diagrams.

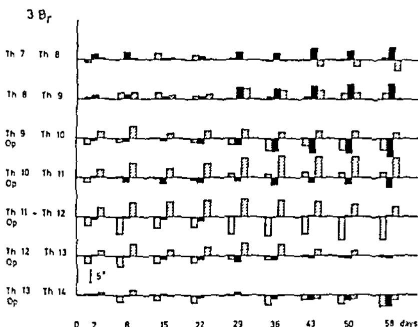


Fig 12 Diagram 3 B_r Principles the same as in diagrams 1 B_r and 2 B_r, i e the rotations for each segment are in relation to its subjacent one and this relation is compared to that in the reference examination

cranial to it representing a slight compensatory curve with convexity to the *left* between Th 7 and Th 8 (diagram 3 B_r, Fig 12)

The mean errors of rigid-body fitting are (Table 3) as great as 0 6 mm (maximal value) Some movements between the indicators have thus occurred

The fourth pig, which was operated upon with destruction of the neurocentral junctions on the left side of Th 10 to Th 12, obtained a kyphosis of about 18° and a scoliosis of the same magnitude with the convexity to the left (diagram 4 A_r, Fig 15) The curvatures are greatest seven days postoperatively and then gradually diminish until the eighth examination The scoliosis then slightly increases and the kyphosis is reversed to a slight lordosis (diagram 4 A_r, Fig 15, stippled staples) The vertex of the curves is at Th 11 regarding both the deviation in the frontal plane and in the sagittal plane (diagram 4 B_r, Fig 16) Th 11 is also slightly rotated towards the convex side about the y-axis (diagram 4 B_r) The cranial transitional zone is at Th 9 Cranially a slight compensatory curve with the convexity to the right (diagram 4 B_r) exists

The fact that the scoliosis has its vertex towards the left side is the reason for the translations along the x-axis being positive (diagram 4 A_{tr}, Fig 17) Translations along the sagittal axis are small but a positive one is encountered between Th 13 and Th 14 (diagram 4 B_{tr}, Fig 18), corresponding to a lordosis between these vertebrae (diagram 4 B_r, Fig 16)

Table 4 gives the mean errors of rigid-body fitting for the fourth pig Concerning Th 7 these errors are great (1 4 mm, maximal value) and concerning the other segments

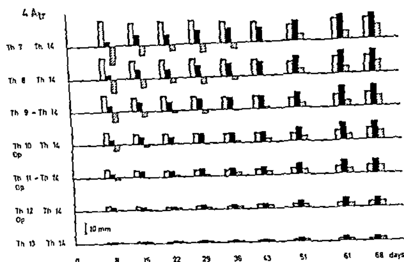


Fig 17 Diagram 4 A_{tr}. Translations for the center of gravity for each segment in relation to a coordinate system with its origin in the center of gravity for Th 14

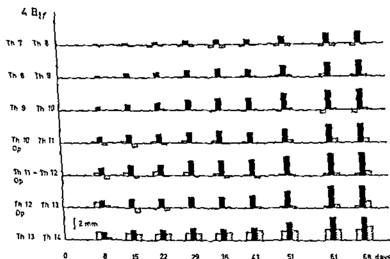


Fig 18 Diagram 4 B_{tr}. The translations of each segment related to a coordinate system with its origin in the subjacent vertebra

From the calculated motions were obtained the standard errors $s_{\phi}=0\ 17°$, $s_{\psi}=0\ 19°$ and $s_{\theta}=0\ 17°$ for the rotation angles ϕ, ψ and θ about the x-, y- and z axes, and the standard errors $s_x=30\ \mu m$, $s_y=13\ \mu m$ and $s_z=50\ \mu m$ for the translations along these axes (n=16 d f) The mean distance between the centers of gravity of adjacent segments is 20 mm For motions between segments with a greater distance between their centers of gravity the standard errors of the translations s_x and s_z will be larger

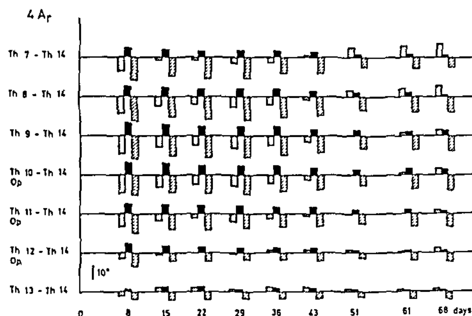


Fig 15 Diagram 4 A_r. Rotations (Eulerian angles) for each segment in relation to the lowermost one Reference examination on the same day as the operation

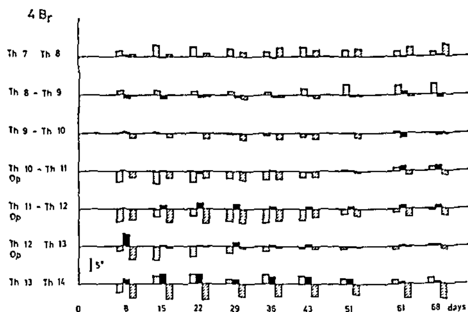


Fig 16 Diagram 4 B_r The rotations of the vertebrae related to the subjacent ones (see legends of previous diagrams)

they are rather small (not exceeding 0 3 mm) The indicators of Th 7 have thus not behaved according to the rigid body model

The precision of the method Four films, each containing eight indicator segments, were double-evaluated Between adjacent segments $n = 4 \times 4 = 16$ independent motions were thus obtained The expected value for each rotation and translation is zero.

of the vertebral canal Then it stays in this periosteum and moves together with it (Fig 19)

The mean errors of rigid body fitting for the first pig (Table 1) reveal that some of the above mentioned processes have occurred in all the segments but particularly in Th 8 The mean errors e_{rb} are in fact significantly different from a rigid body motion as they are all but one larger than 80 The principles of the method cannot, however, be altered by this fact The indicators of the second pig behaved well according to the rigid body model Significant difference from that is registered 24 times of the 72 measurements (Table 2) Concerning the third pig and the fourth pig only one segment (Th 8, pig 4) has behaved completely according to the rigid-body model (at the one sided 1 % level, n=32 d f) (Tables 3, 4) The mean errors of rigid body model for Th 7 of the fourth pig are even as great as 1 4 mm at the last examination Still the general appearance of rotations and translations for this segment is as revealed in the diagrams not altered in relation to the movements of the other segments

The second prerequisite was that the whole of the body in which the indicators were situated could be considered a rigid body In a growing animal, naturally the vertebrae grow too This occurs as endochondral growth in the end plates of the vertebral bodies in the neurocentral junctions and in the apophyses of the intervertebral, spinous and transverse processes and as apposition outside and resorption inside the vertebral canal Thus, the indicators have been situated in a bone that only within a limited area can be regarded as a rigid body, and it is in fact only the movements of this particular area, the posterior elements of the vertebrae, that have been analysed

The pigs have developed more or less marked kyphoscoliosis It is a well known fact that the human scoliosis most often is accompanied by lordosis Thus, in animals provoked curves are not always comparable with human ones, a fact that should be borne in mind when dealing with experimentally provoked scoliosis

The last pig was operated upon in an attempt to destroy the neurocentral junctions in three segments on the left side (OTTANDER 1963) This attempt was successful on one level only, Th 12 (Fig 20) If the scoliosis was a sequel of the operative trauma or if it depended on the epiphyseodesis is uncertain If the latter had been the case it would not have disappeared but would probably have continued Consequently, the problem of inhibited growth in the neurocentral junctions during the development of scoliosis is not solved by this investigation

SUMMARY

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Fig 19

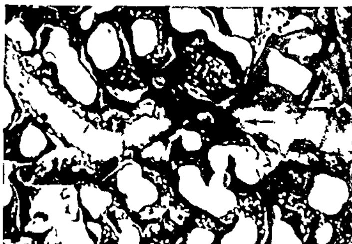


Fig 20

Fig 19 Axial view of a vertebra with indicators inserted One indicator is situated corresponding to the periosteum of the spinal canal

Fig 20 Fourth pig Microscopy of the left neurocentral junction (25 × magnification) of Th 12 Bony fusion exists through the junction

due to the lever effects of the rotation angle errors about the z-axis and the x-axis, respectively Thus, the standard errors of these translations between the outermost segments will be of the magnitude 500 μm It should be noted that these method errors are barely visible in the graphical representations

Discussion

The method described presupposes that (a) the tantalum indicators may be considered stable in relation to each other and (b) that the whole of the body in which they are situated behaves as a rigid body Neither of these prerequisites are completely fulfilled

As has been accounted for in the results, movements have occurred between the indicators in several segments Possible explanations for such movements are that the indicators have not been placed within the bone or that a growth process has influenced their position The growth processes are endochondral and perichondral Endochondral growth takes place in the apophysis of a process and perichondral growth exists on the surface of the arches (KARAHARJU 1967) Thus some indicators may have been placed in an apophysis of an articular process where endochondral growth occurs The most probable explanation for the movement in question is, however, some influence on the indicators of the perichondral growth process This is because this process includes resorption of the bony surface inside the vertebral canal (KARAHARJU 1967) So when an indicator that originally is placed within the arch is reached by the resorption process, it will also be reached by the periosteum

of the vertebral canal Then it stays in this periosteum and moves together with it (Fig 19)

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The second prerequisite was that the whole of the body in which the indicators were situated could be considered a rigid body In a growing animal, naturally, the *vertebrae* grow too This occurs as endochondral growth in the end plates of the vertebral bodies, in the neurocentral junctions and in the apophyses of the intervertebral, spinous and transverse processes and as apposition outside and resorption inside the vertebral canal Thus, the indicators have been situated in a bone that only *within a limited* area can be regarded as a rigid body, and it is in fact only the movements of this particular area, the posterior elements of the vertebrae, that have been analysed

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SUMMARY

A three-dimensional method to analyse the kinematics of the spine has been applied to four pigs with experimentally provoked scoliosis *The advantages and limitations* of the method are discussed and some interesting facts concerning the provoked curves are emphasized

ZUSAMMENFASSUNG

Eine dreidimensionale Methode zur Analyse der Kinematik der Wirbelsaule wurde bei vier Schweinen mit experimentell hervorgerufener Skoliose verwendet Die Vorteile und Begrenzungen der Methode werden diskutiert und einige interessante Verhalten hinsichtlich der erzielten Kurven hervorgehoben

RÉSUMÉ

Une méthode d'analyse tri-dimensionnelle de la cinématique de la colonne vertébrale a été appliquée a 4 porcs ayant une scoliose provoquée expérimentalement Les auteurs examinent les avantages et les limites de cette méthode et soulignent plusieurs faits intéressants concernant les courbures provoquées

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Book review

UNTERSUCHUNGEN ZUR STATIK UND DYNAMIK DER KINDLICHEN HALSWIRBELSÄULE. Der Aussagewert seitlicher Röntgenaufnahmen. Die Wirbelsäule in Forschung und Praxis, Band 50. 51 *pages with 8 figures, 20 tables and 100 references.* Hippokrates Verlag Stuttgart 1971.

The author has examined 120 normal children between 3 and 14 years of age: 5 boys and 5 girls for each year. In all cases, 3 lateral films of the cervical spine were taken for analyzing the dynamics of the cervical spine in maximum extension and flexion, and in resting position.

Among the statistically more significant findings is the correlation between the shape of the cervical spine and the stature of the patient. The shape is classified according to a scale from straight, via sublordosis and lordosis, to hyperlordosis. A straight cervical spine in resting position is associated with tall stature. The corresponding relationship with increased body weight is selectively valid for the cases with hyperlordosis.

The total mobility of the region C2 to C7 is more extensive in children than in adults and particularly in the age group 11 to 14 years. The mobility of the upper cervical spine, including the atloido occipital joints does not vary with age. The C1 to C2 segment, however, is more movable in children than in adults.

The normally occurring stepwise anteroposterior displacement has been analyzed for the C2 to C4 region. More than 3 mm of total movement occurred in about 60 per cent of the children at the C2 to C3 level, and in 30 per cent at the C3 to C4 level. Anterior displacement of more than 3 mm at C2 to C3 is found in 6 per cent.

The maximum distance between the posterior surface of the anterior arch of the atlas and the anterior surface of the odontoid process was found to be 4 mm. On the average, the distance is significantly greater during childhood compared with the situation in adults.

The wide experience of the author is reflected in the text and the book bears marks of scrupulous attention to detail. It may be useful at least to orthopedic and pediatric radiologists.

Hans Ringertz

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OBJECTIVE SYMMETRY DETECTOR METHOD FOR GAMMAENCEPHALOGRAPHY

V. Variation in the subjective analysis of brain scintigrams

MAGNUS LIND

Brain scintigraphy using gamma-emitting isotopes is a common method for the screening of patients with possible brain lesions, because of its high safety, convenience and diagnostic accuracy The large patient group submitted for screening by this method is characterized by a large proportion of cases without lesions and consequently with a low incidence of pathology Hence, even a relatively small proportion of false positive or borderline results causes a large number of patients unnecessarily to be subjected to further diagnostic procedures Therefore, it is of particular importance to restrict the different sources of variation and to improve the diagnostic accuracy of brain scintigraphy when used for screening purposes (BURROWS 1972, YOUNG & ROCKETT 1972)

Many sources of variation exist in gammaencephalography, for instance normal biologic variation, the statistical fluctuation of the gammaphoton emitting process, detector efficiency, detector measuring geometry, characteristics of data transfer systems and finally, variation in the subjective interpretation of results as well as in the variation in the clinician's interpretation of the observer's report (LUSTED 1968, MALLARD 1972)

From the Departments of Neuroradiology and Otolaryngology, Karolinska Sjukhuset, S 104 01 Stockholm, Sweden Submitted for publication 17 June 1975

The objective symmetry detector method for gammaencephalography has been previously described in detail (LARSSON et coll 1975, LIND & LARSSON 1975, LIND et coll 1975) Different sources of variation were analyzed and restricted (LARSSON et coll, LIND et coll) The variation caused by the subjective interpretation of results and the subjective evaluation of observer's reports was avoided by use of the semi automatic interpretation designed for the objective symmetry detector method

The purpose of this report is to evaluate the advantages of the objective interpretation of results in comparison with the subjective interpretation of images at brain scintigraphy

Material

The material consisted of 103 patients, examined and grouped A–D according to their diagnosis

Group A Twenty-nine patients, no suggestion of brain lesion They were used as a reference group for the symmetry detector method and have been presented in detail previously (LIND et coll)

Group B Forty-eight patients, clinically, gross brain lesion was not considered likely They were examined as outpatients at the Department of Neurology, Karolinska Sjukhuset, because of headache or epileptic attacks without further signs or symptoms of brain lesion at clinical examination The scintigrams had been interpreted as normal and no further neuroradiologic examination was considered necessary

Group C Eighteen patients intracranial neoplasm confirmed microscopically These patients were examined both by conventional brain scintigraphy and by the symmetry detector method They all belonged to a group of 37 patients with intracranial neoplasm, the selection principles of these patients have been presented in detail previously (group IV, LIND 1975)

Group D 8 patients, diagnosis uncertain They were examined clinically and by conventional neuroradiology, scintigraphy and electroencephalography on primary suggestion of brain lesion, but no conclusive diagnosis was reached

Methods

The objective symmetry detector method has been described previously (LIND et coll) A premedication of 400 mg $KClO_4$ was given orally 30 to 60 min before the intravenous administration of 10 mCi $^{99}Tc^{m}O_4$ The measuring procedure started about 30 min after the injection of the nuclide and was completed within 30 minutes Two NaI detectors face to face on the same axis and shielded by collimators 30 cm in length with 3 cm × 3 cm square apertures were used (see Fig 2, LARSSON et coll)

Table

Classification used both for the subjective classification of brain scintigrams and the objective classification made by the symmetry detector method

Class	Denomination	SD_{max}	Intended level of probability
I	Definitely normal	0–3 0	1 00–0 95
II	Probably normal	3 0–3 5	0 95–0 50
III	Probably abnormal	3 5–4 0	0 50–0 05
IV	Definitely abnormal	4 0–∞	0 05–0 00

The nuclide distribution was determined from measurements over 24 subregions of the head in a constant pattern, given by a positioning diagram for approximate alignment of the individual size and shape of the skull (see Fig 1, LIND et coll) The values obtained were recorded on punched paper tape and 9 evaluation parameters were calculated for each subregion, in all 208 (LIND et coll)

The normal mean values and standard deviations (SD) of these 208 evaluation parameters were obtained from the reference group of 29 patients (group A) without brain lesions The values obtained have been reported previously and were used as the basis for evaluation (LIND et coll)

The maximum deviation from the normal mean value in any of the 208 evaluation parameters was expressed as the number of SD (SD_{max}) and used as a criterion (LIND et coll , LARSSON & LIND) The $^{99}Tc^{m}O_4$ distribution in the skull was then objectively classified as demonstrated in the Table (LIND et coll , LARSSON & LIND)

Brain scintigraphy was performed with a Picker Magna Scanner III collimated by a 31 hole collimator (focus distance 9 cm, scan speed 100 cm/min, line-spacing 0 3 cm, background cut off 30–60 per cent, dot factor 8, time constant 0 1 and pulse height discriminator 120–160 keV) The distance between the collimator and the skull was about 3 to 5 cm

Four projections of the skull were used anterior, posterior, right and left lateral projections A dose of 0 4 g $KClO_4$ was given orally 30 to 60 min before the intravenous injection of 10 mCi $^{99}Tc^{m}O_4$ Scanning was started about 15 min after the injection of the nuclide, and was completed within about 60 to 90 min The order of the various projections was not constant

The scintigrams from patients in groups B–D were codified, the original identifications were covered and they were all randomized in one group, altogether 74 examinations The scintigraphic findings were analyzed and classified by 10 radiologists without internal communication or any clue to the identity of the patients Five participants were fully trained neuroradiologists and 5 were qualified general radiologists with a limited experience of neuroradiology

The interpreters were instructed to estimate the probability (p) of the findings to

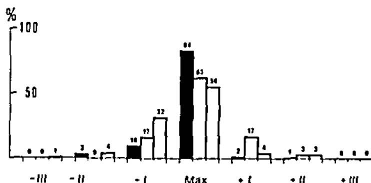


Fig 1 Variation of the subjective analysis of brain scintigrams Ten interpreters have classified each brain scintigram according to the table The most frequent classification of each case is named 'Max' The relative number of classifications in class 'Max' and in the classes higher and lower in number according to the table are indicated in the diagram Black bars group C, intracranial neoplasm White bars group B, control cases Dotted bars group D, undiagnosed cases

be normal or abnormal, and then to classify them as demonstrated in the Table The boundaries between the four classes were defined by $p = 0.95$, 0.50 and 0.05, respectively This subjective classification was intended to correspond to the objective classification made by the symmetry detector method (LIND & LARSSON)

Each complete scintigraphy was thus classified ten times and the most frequent class (I, II, III or IV, Table) of the ten classifications was named 'Max' Classes higher in number (Table) were named +I, +II and +III, respectively, and classes lower in number were named −I, −II and −III, respectively

The relative distribution of all 740 classifications among −III, −II, −I, Max, +I, +II and +III, was calculated The corresponding distributions of classifications were calculated for the patient groups B (no brain lesion), C (intracranial neoplasm) and D (undiagnosed cases), respectively The results were illustrated by pile diagrams

Results

All 740 interpretations would have been registered in class 'Max', if the variations caused by the observers had been negligible Hence, the distribution around 'Max' demonstrates the importance of variation caused by the observer From Fig 1 it is seen that patient group C (intracranial neoplasm) had the smallest variation around 'Max' and patient group D (undiagnosed cases) the largest variation around 'Max' Classifications with the objective symmetry detector method—without observer's variation—is in Fig 2 compared to the variation around 'Max' among all 740 scintigram interpretations, 32 per cent of these 740 classifications were outside class 'Max'

Discussion

Sensitivity has been defined as the number of evaluation parameter units per unit of evaluated effect of interest (for instance, local accumulation of nuclide), and



Fig. 2. Comparison between the objective symmetry detector method and the subjective analysis of brain scintigrams The 740 classifications by the ten interpreters are presented as in Fig. 1 The classifications of the objective symmetry detector method are objective and hence there is no variation Black bars symmetry detector method Dotted bars scanner

detectability has been defined as the size of the smallest effect of interest, which can be detected outside the normal range by the evaluation parameter used with a significance that corresponds to a certain number of standard deviations (LARSSON et coll , LIND & LARSSON)

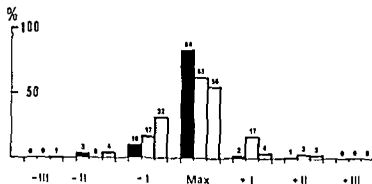
As far as the sensitivity relative to the effect of interest is unchanged, any reduction of variation increases the detectability of the method

The number of patients examined was not large and therefore, it was necessary to decide whether the material was sufficient to demonstrate the variation caused by subjective interpretation For this purpose, the three groups B, C and D were considered It may be assumed that the group of definite intracranial neoplasms (C) should have the smallest variation of interpretation because a considerable proportion of evident scintigraphic findings should without hesitation be classified as definitely abnormal (class IV) It may also be assumed that the group of undiagnosed cases (group D) should have the largest variation of interpretation, because all these cases were borderline cases The agreement between these assumptions and the results obtained is demonstrated in Fig 1 It was thus reasonable to consider the material as sufficient to demonstrate the approximate importance of variation caused by subjective interpretation

No less than 32 per cent of the 740 interpretations of brain scintigrams were classified outside the most frequent class ('Max') This indicates that the variation caused by subjective interpretation was considerable (Fig 2)

However, this variation was to a large extent due to uncertain separation between class I and II or III and IV, respectively (Table) This uncertainty can be related to the observer's understanding of the scintigraphic image or to differences in the use of the classification system The latter effect is comparable to the variation caused by differences in linguistic expression and comprehension between the observer and the clinician in routine work

The considerable uncertainty of the subjective classification of scintigraphic findings makes rational medical decision-making difficult, especially in screening work, because too many borderline cases or false positive cases might be referred to further,



White bars group B, control cases Dotted bars group D, undiagnosed cases

be normal or abnormal, and then to classify them as demonstrated in the Table The boundaries between the four classes were defined by p=0 95, 0 50 and 0 05, respectively *This subjective classification was intended to correspond to the objective* classification made by the symmetry detector method (LIND & LARSSON)

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sometimes inconvenient or hazardous, examination procedures The large variation caused by subjective interpretation and also differences in linguistic expression and comprehension are avoided by using the objective symmetry detector method However, these advantages might be outweighed by less sensitivity to some effects of interest (for instance brain lesions close to the skull base) (LIND 1975) The diagnostic accuracy and clinical value of the methods must therefore be compared directly from patient material, this is the subject of a separate report (LIND, to be published)

SUMMARY

The variation caused by the subjective interpretation of brain scintigrams was evaluated and found considerable It was concluded that the objective analysis of results offered by the objective symmetry detector method for gammaencephalography is advantageous especially in the screening of large patient materials with a low incidence of brain lesion cases

ZUSAMMENFASSUNG

Die Unterschiede der subjektiven Interpretation von Gehirnszintigrammen wurde untersucht, diese waren erheblich Der Verfasser kommt zu dem Schluss, dass die objektive Analyse der Ergebnisse, welche die objektive symmetrische Detektormethode fur die Gamma encephalographie bietet, vorteilhaft ist, besonders bei Massenuntersuchungen eines grossen Patientenmaterials mit einer niedrigen Frequenz von Gehirnveranderungen

RÉSUMÉ

L'auteur a évalué les variations dues à l interpretation subjective des scintigraphies cérébrales et les a trouvées considérables Il conclut que les analyses objectives des résultats fournis par la méthode de detecteur objectif de symétrie pour la gammaencéphalographie sont avantageuses, en particulier pour le dépistage de grandes séries de patients comprenant une faible proportion de lésions cérébrales

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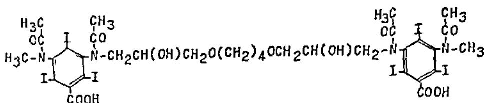


Fig 1 Chemical structure of the new contrast agent in its acid form Ph DZ 59B is the methyl glucamine salt of this acid

Experiments in dogs

Nine mongrel dogs weighing between 13 and 18 kg, without any signs of disease, were used Myelography was performed once in 3 dogs, twice in 5 dogs and three times in one dog Fourteen examinations were made with an aqueous solution containing 57 g Ph DZ 59B per 100 ml, corresponding to 235 mg I/ml Ph DZ 59B is the methylglucamine salt of the acid whose chemical structure appears in Fig 1. The other two examinations were made with Conray Meglumin 282, which is an aqueous solution containing 60 g methylglucamine iothalamate per 100 ml, corresponding to 282 mg I/ml

In all dogs the contrast medium was injected into the subarachnoid space at the level of L 4–5 No premedication or anaesthesia was administered In the first 6 experiments the injection was given intermittently, by hand In the last 10 (experiments 7 to 16), the medium was injected by an automatic pressure syringe at a constant rate The filling of the subarachnoid space was observed fluoroscopically by an image-intensifier television unit During the examination the dogs were positioned first on the left side and subsequently in the supine position The amount of contrast medium, the dose per kg body weight and the method of injection are given in Table 1 The largest dose was 2 2 ml and the lowest 0 5 ml/kg body weight The injection times varied from 5 to 20 minutes The blood pressure was measured via a catheter inserted in the common carotid artery in 4 experiments (12 to 15), in 2 dogs (Nos 7 and 8) The pressure in the subarachnoid space was recorded in 5 experiments (12 to 16) in 3 dogs, by an electromanometer and Mingograf 82

Three months following examination with Ph DZ 59B, 2 dogs were examined with Conray Meglumin (experiments 4 and 6) One of them received 17 ml in 8 minutes and the other 13 ml in 5 minutes

Results With Ph DZ 59B the subarachnoid space was well filled and the spinal cord and the roots could clearly be demonstrated from the lumbar region up to the head, where the basal cisterns were also filled The concentration of the medium was good and films of diagnostic value could be obtained for 45 minutes after the injection In some cases after injection of large doses, contrast medium also appeared in the epidural space (Fig 2)

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EXPERIMENTS WITH A NEW CONTRAST MEDIUM IN MYELOGRAPHY

L. BJÖRK, U. ERIKSON, B. INGELMAN and G. LINDBLAD

More than 40 years ago ARNELL & LIDSTRÖM (1931) introduced an aqueous solution of methiodal for lumbar myelography. The technique of this examination was later improved by LINDBLOM (1946), among others. Methiodal was widely used for many years but necessitated spinal anaesthesia.

More recently other water soluble contrast media have been tested in lumbar myelography, for example methylglucamine iothalamate (CAMPBELL et coll. 1964), methylglucamine iocarmate (GONSETTE & ANDRÉ-BALISAUX 1970) and metrizamide (Acta radiol. Suppl. No. 335, 1973). These contrast media have been employed without spinal anaesthesia. However, convulsions have been reported in association with methylglucamine iothalamate (BOISEN & LINDHOLMER 1971).

Previously a new dimeric water soluble contrast medium, Ph DZ 59B, for use in angiography, arthrography and hysterosalpingography has been reported (BJÖRK et coll. 1969, 1970, 1972 a, b). The favourable results obtained gave us the incentive to test this compound in myelography in experimental animals. In dogs and large cats injections for myelography could be carried out successfully; some preliminary experiments in smaller animals (rats, rabbits and small monkeys) have also been carried out.

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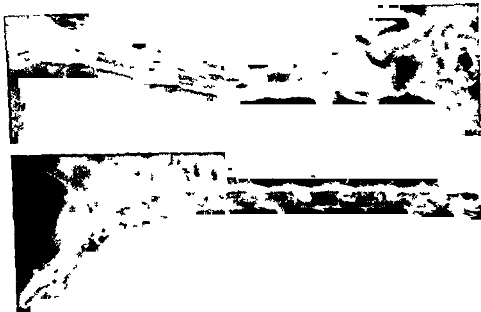


Fig 2 Myelography of a dog Cervical and thoraco lumbar regions No anaesthesia or premedication

Table 2

The pressure in the subarachnoid space in 5 dogs before and after injection of Ph DZ 59B

Experiment No	Dose ml	ml kg	Pressure in subarachnoid space		Stretching of hind legs
			Before inj	After inj	
12	13	1 0	50	127	+
13	14	1 0	20	200	+
14	13	1 0	7	50	0
15	18	1 3	10	50	0
16	18	1 0	20	200	+

(No 13) 3 5 and 2 0 ml of 0 9 % NaCl solution were injected subsequent to the injection of contrast medium These injections also resulted in an increase in pressure of the cerebrospinal fluid and the dogs showed signs of pain (Fig 3)

In experiments 12, 13 and 16 the pressure in the subarachnoid space increased to high levels and stretching reflexes were noted (Table 2) In experiments 14 and 15 leakage occurred at the puncture site and the pressure did not rise to an equally high level no stretching reflexes occurred

Table 1

Reactions in dogs following subarachnoid injections of contrast media

Experiment No	Dog No	Contrast medium	Dose			Injection			Reactions
			ml	ml/kg	mg I/kg	Rate ml/min	Time min	Method	
1	1	Ph DZ 59B	8	0 5	120	—	10	Interm	No reactions
2	2	Ph DZ 59B	35	2 2	520	—	20	Interm	Stretching of hind legs
3	3	Ph DZ 59B	30	1 9	450	—	20	Interm	Stretching of hind legs
4	2	Conray	17	1 1	310	—	8	Interm	Restlessness salivation (nausea) stretching of hind legs and convulsions
5	4	Ph DZ 59B	35	2 2	520	—	10	Interm	Stretching of hind legs
6	3	Conray	13	0 8	230	—	5	Interm	Restlessness, salivation (nausea) severe convulsions, urination
7	1	Ph DZ 59B	22	1 4	330	1 5	15	Autom	Stretching of hind legs
8	2	Ph DZ 59B	22	1 4	330	1 5	15	Autom	Stretching of hind legs
9	4	Ph DZ 59B	16	1 0	230	1 6	10	Autom	Stretching of hind legs
10	5	Ph DZ 59B	21	1 3	300	1 4	15	Autom	Stretching of hind legs
11	6	Ph DZ 59B	21	1 5	350	1 5	14	Autom	Stretching of hind legs
12	7	Ph DZ 59B	13	1 0	230	1 7	7 5	Autom	Stretching of hind legs and tail
13	8	Ph DZ 59B	14	1 0	230	1 9	7 5	Autom	Stretching of hind legs
14	7	Ph DZ 59B	13	1 0	230	1 3	10	Autom	No reactions
15	8	Ph DZ 59B	18	1 3	300	1 5	12	Autom	No reactions
16	9	Ph DZ 59B	18	1 0	230	2 0	9	Autom	Stretching of hind legs

Only slight reactions occurred even after large doses of Ph DZ 59B, e g stretching of the hind legs (Table 1) When such an effect was observed the injection was discontinued, and the reaction then disappeared The observation time was 3 days The blood pressure remained constant (experiments 12 to 15)

In the dog injected with 17 ml of Conray Meglumin, salivation, nausea, marked restlessness and convulsions were observed The dog injected with 13 ml of this medium became nauseated, the injection was discontinued but severe convulsions developed (Table 1) Nembutal was administered intravenously, but had no effect and the dog died Because of these severe reactions, the comparative tests with Conray Meglumin were discontinued

The pressure in the subarachnoid space increased during the injection of contrast medium (Table 2, Fig 3, experiments 12 to 16) After discontinuation of the injection, the pressure returned to the pre-injection level within one minute Additional small doses, however, were followed by repeated increases in pressure In one experiment

Table 3

Reactions in monkeys following subarachnoid injections of contrast media

Contrast medium	Number of monkeys	Dose ml/kg	Obs time hours	No reactions	Reactions		
					Convulsions	Vomiting	Death
Conray Meglumin	5	0 8	45	1	2	1	1 after 3 hours
Dimer X	5	0 8	45	3	2	0	2 after 10 and 35 hours
Ph DZ 59B	9	0 8	45	7	0	0	2 after 10 hours
	4	0 5	45	3	1	0	1 after 12 hours

Experiments in monkeys

Twenty three monkeys (Cynomolgus macaca fascicularis) weighing 1 650 to 2 700 g were used They were imported from Indonesia and were apparently healthy

The following contrast media were injected Conray Meglumin, 282 mg I/ml, diluted with distilled water to an iodine content of 235 mg/ml Dimer-X (dimeglumine iocarmate), 280 mg I/ml, diluted to 235 mg I/ml, and Ph DZ 59B, 235 mg I/ml, not diluted

The animals were anaesthetized with Sernylan (Parke Davis) in a dose of 1 mg/kg body weight given intramuscularly

The contrast medium was injected into the lumbar region, in a dose of 0 5 to 0 8 ml/kg body weight The injection was given continuously by hand under fluoroscopic control with an image intensifier television unit, in 30 to 60 seconds

The monkeys were observed for up to 45 hours following the injection

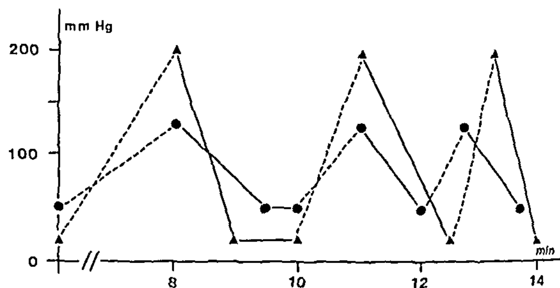
Results Of the 5 monkeys injected with Conray Meglumin, one died and 2 had convulsions, one vomited and one was free of symptoms Following injection of Dimer-X in 5 monkeys, 2 had convulsions and died, and 3 had no reactions

Of 13 monkeys injected with Ph DZ 59B, 3 died, one of these three had convulsions (Table 3)

Experiments in rabbits

Twenty three albino rabbits weighing 2 300 to 4 600 g were used Ph DZ 59B (235 mg I/ml) and Conray Meglumin (diluted to 235 mg I/ml with distilled water) were injected in doses from 0 1 to 0 3 ml/kg body weight The animals were anaesthetized with Pentothal sodium (Abbott) In most cases the injections were controlled radiographically

Results All animals reacted fairly similarly irrespective of the type, dose and concentration of contrast medium As they recovered from the anaesthesia, neurologic



[illegible] induced increases in pressure The injections were stopped when stretching reflexes were observed Full lines continuous pressure recordings Dotted lines = intermittent pressure recordings

Experiments in cats

Five large cats weighing 3 to 5 kg were used. In each cat the myelography was repeated 4 times at intervals of 2 to 3 days On each occasion 1 ml/kg body weight of the aqueous solution of Ph DZ 59B (235 mg I/ml) was injected into the subarachnoid space in the posterior part of the loin The cats were anaesthetized with a short-acting barbiturate (Pentothal sodium) during the injection, which was controlled radiographically

Three days after the last injection the cats were killed and specimens from the spinal cord and canal at 5 different levels were prepared for microscopy by a conventional histologic technique The sections were stained with eosin and haematoxylin and van Gieson's stain

Results Films of high quality were obtained The subarachnoid space was always well filled

No untoward reactions were observed following the injections of Ph DZ 59B, either during or after the short anaesthesia The cats began to wake up from the anaesthesia about 20 to 30 minutes after the injection of contrast medium

Microscopy of the spinal cord and the meninges revealed no abnormalities

media, but Ph DZ 59B seems to give fewer adverse reactions than the monomeric and the other dimeric compound

Rabbits and rats exhibited a low tolerance to subarachnoid injections of all contrast media used in these preliminary experiments The reason for this remains unclear, although technical difficulties may have been partly responsible

SUMMARY

A new dimeric contrast medium, Ph DZ 59B, was injected into the subarachnoid space in experimental animals Excellent films were invariably obtained Ph DZ 59B was well tolerated by dogs and cats and relatively well by monkeys

ZUSAMMENFASSUNG

Ein neues Kontrastmittel von Dimertyp, Ph DZ 59B, wurde experimentellen Tieren in den Subarachnoidal-Raum injiziert Ausgezeichnete Röntgenbilder wurden ohne Ausnahme erhalten Ph DZ 59B wurde gut von Hunden und Katzen und relativ gut von Affen vertragen

RÉSUMÉ

Un nouveau moyen de contraste dimère, le Ph DZ 59B, a été injecté dans l'espace sous-arachnoïdien d'animaux d'expérience On a obtenu dans tous les cas d'excellents films Le Ph DZ 59B a été bien toléré par les chiens et les chats et relativement bien par les singes

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disturbances such as stretching of the hind legs, paralysis or convulsions were invariably observed Most animals were killed by an overdose of Nembutal because of the severity of the reactions

Experiments in rats

Forty-three rats of the Sprague-Dawley strain were used in the same way as the rabbits The medium was injected under fluoroscopic control with an image-intensifier television unit The following contrast media were used Ph DZ 59B (235 mg I/ml), Conray Meglumin 282 diluted with distilled water to 235 mg I/ml and Dimer-X diluted with distilled water to 235 mg I/ml The dosages used were 1 0, 0 6 and 0 3 ml/kg body weight, respectively, for the three contrast media

Results Different types of nervous symptoms such as muscle cramp, signs of pain, balance disturbances and convulsions developed in all animals as they recovered from the anaesthesia There were no differences in this respect between the contrast media or dosage groups

Discussion

The technique of lumbar puncture and injection of contrast medium into the subarachnoid space for lumbar myelography is obviously easier in large animals than in small In the latter leakage through the puncture hole and deposition of contrast medium epidurally or subdurally cannot be completely avoided The use of fluoroscopy minimizes the risk of such events, but the unusual appearance of an overdistended subarachnoid space associated with leakage into the epidural space must always be kept in mind

Ph DZ 59B gave excellent filling of the subarachnoid space in all the animals and the concentration of the medium remained adequate for about 45 minutes with the doses used in the dogs This provides an opportunity for unhurried examination and ample time for repeated and additional films when necessary

The tolerance to Ph DZ 59B was excellent in unanaesthetized dogs as well as in lightly anaesthetized cats An interesting finding was that the clinical signs in the dogs following injections of large amounts of Ph DZ 59B into the subarachnoid space were related to the pressure in this space When the pressure rose above a certain level stretching reflexes in the legs occurred These disappeared when the pressure decreased The same symptoms could also be produced by injecting saline into the subarachnoid space This may indicate that the rise in pressure contributes to side effects in myelography and relief of pressure by aspiration of cerebrospinal fluid would probably be beneficial This was attempted in the dogs but usually only very minimal amounts of fluid could be withdrawn through the needle before it became blocked, probably by minute detached pieces of meninges

The monkeys tolerated the contrast media relatively well In these small groups of animals there was no obvious difference in mortality between the three contrast

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ADVERSE EFFECTS OF LUMBAR MYELOGRAPHY WITH AMIPAQUE AND DIMER-X

LARS IRSTAM and ULLA SELLDÉN

For several years dimeglumine iocarmate (Dimer-X) was the least toxic water-soluble contrast medium available for lumbar myelography. Like other media, it has a serious drawback, viz. a slight but definite tendency to provoke myoclonic spasms (BAUMGARTNER et coll. 1970, GONSETTE 1971, AHLGREN 1972, IRSTAM 1973, SKALPE & TALLE 1973). This undesired effect can be substantially mitigated by premedication with diazepam (Valium) and by prevention of the passage of the contrast above the level of the lower margin of the first lumbar vertebra, i.e. hindrance of contact with the medullary cone (IRSTAM & SELLDÉN 1975). It was also found that EEG abnormalities may be recorded 3 hours after Dimer-X myelography, i.e. when the contrast has reached the brain stem area and the basal parts of the brain. As compared to the premyelographic EEG, no alterations were recorded 24 hours after lumbar myelography. The EEG changes were slight and only 1 of 90 cases presented slight paroxysmal changes due to the medium, no simultaneous side effects were observed in this particular case. EEG abnormalities were equally distributed among patients with and without side reactions.

A new non ionic compound, metrizamide (Amipaque), has recently been introduced for use in the subarachnoid space. Judging from investigations in laboratory

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A new non ionic compound, metrizamide (Amipaque), has recently been introduced for use in the subarachnoid space Judging from investigations in laboratory

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animals, the central nervous system tolerates this medium exceptionally well (ALMEN 1973, GONSETTE 1973, GREPE & WIDÉN 1973, OFTEDAL & SAWHNEY 1973, SALVESEN 1973). The epileptogenic effect of the compound is far less than that of any other water-soluble contrast medium (OFTEDAL & KAYED 1973, GONSETTE 1973). Preliminary clinical experience with the medium has been encouraging (GONSETTE 1973, HINDMARSH 1973, SKALPE et coll. 1973). It has been shown by HINDMARSH (1975 a) that Amipaque may be used in man in the examination of the whole spinal subarachnoid space, by GREPE (1975) of the basal cisterns as well as by GONSETTE (1973) of the cortex of the brain without serious side effects. However, EEG alterations of slow wave type have occasionally been recorded indicating an irritating effect on the basal part of di- or mesencephalon (KAADA 1973).

Minor side effects of lumbar myelography with Amipaque are as equally common as of Dimer-X (HINDMARSH 1975 b). No seizures occurred in his Amipaque series but 1 of the 34 patients in the Dimer-X group had grand-mal seizures and 2 had myoclonic spasms. The dose of Dimer-X was large, in many instances much larger than the recommended maximum dose. But the level of the contrast medium was never allowed to extend above the first lumbar vertebra, i.e. never to come into contact with the medullary cone. EEG recordings revealed paroxysmal abnormalities in 2 of the patients of the Dimer-X group and in 1 in the Amipaque group. None of these 3 patients were identical with those who had seizures. However, EEG was always recorded 24 hours after the myelography and never in connection with the spasms occurring 3 and 12 hours, respectively, after injection of contrast medium. Thus, no alterations appeared in the 24-hour EEG in the 2 myoclonus cases.

SKALPE et coll. (1973) observed no serious side effects in a series of 100 lumbar myelographies with Amipaque. Thus, no seizures occurred. Headache was reported by 37 patients, including 8 in whom it was intense and lasted for up to one week. Continuous EEG recordings disclosed minimal slow wave activity before and after myelography in 2 out of 18 patients examined, such alterations were regarded as lying within the limits of normal fluctuations. Of the same material, 79 patients were submitted to premyelographic EEG and to a further recording 24 hours after myelography. Additional transient slow wave activity was found in 13 (16 %) of the 24-hour recordings (KAADA 1973), he also pointed out that a previous injury to the brain, as suggested by the presence of EEG abnormalities, appeared to be a site of lesser resistance to Amipaque.

Seizures occurred in one case of cervical myelography with Amipaque (HINDMARSH et coll. 1975) and HINDMARSH (1975 b) also reported one case with a paroxysmal EEG 24 hours after lumbar myelography with Amipaque. At the time of myelography these 2 patients were treated with a phenothiazine derivative. HINDMARSH et coll. have suggested that phenothiazine derivatives might interact with Amipaque in such a way as to lower the 'convulsion threshold' to a level at which the comparably weak epileptogenic effect of Amipaque might be strong enough to elicit seizures.

Eclampsia occurred in 7 patients in a previous personal Dimer-X series (IRSTAM

1973) In those cases hyperreflexia of the legs was observed for up to several days after the seizures had ended IRSTAM & SELLDEN have observed some Dimer X cases with an increase of the patellar tendon reflexes without other simultaneous side effects This hyperreflexia was found 1 to 4 hours after myelography Neurologic examination of these patients revealed no signs of irritation of the upper limbs, but all routinely examined reflexes of the leg on the side with increased patellar tendon reflexes were increased The abnormality promptly disappeared after intravenous injection of diazepam

On the other hand, no neurologic disturbances were found by HINDMARSH (1975 b), 24 hours after lumbar myelography with Amipaque or Dimer-X

The purpose of the present investigation was (1) to compare the reactions to lumbar myelography with Amipaque and Dimer X, in a dose not exceeding the recommended maximum dose, (2) to ascertain the occurrence, nature and latency of EEG changes if any, and (3) to examine the immediate side effects and possible EEG abnormalities for any inter correlation

Materials and Methods

The patients to be examined with either Amipaque or Dimer X were randomly selected In all 100 lumbar myelographies were performed 50 with Amipaque and 50 with Dimer X Two of the patients in the Amipaque series and 1 in the Dimer-X series were examined twice, at the first examination the contrast medium was injected partly subdurally and the films were non informative Repeat myelography was performed within 14 days and both examinations were included in the material Only the examiner, performing the myelography, was aware of the medium used Apart from the type of contrast medium, all the patients were treated in the same way

A previous history of epilepsy or severe alcoholism was regarded as a contraindication Iodine allergy was considered a relative contraindication but was not encountered in the present material

It is known that also several drugs other than phenothiazine derivatives may lower the convulsion threshold' Such drugs are MAO inhibitors and tricyclic antidepressants antihistamines with a sedative effect, analeptics and CNS stimulants, antifungals and antimycobacterials (JARVIK 1970, ALEXANDER et coll 1971) If, as assumed by HINDMARSH et coll, phenothiazine derivatives interact with Amipaque and thereby lower the 'convulsion threshold', all the above mentioned types of drugs should be contraindicated at myelography with any water soluble contrast medium In the present series, all these drugs were withdrawn from at least 48 hours before, until 48 hours after, myelography For many years one of the patients of the Amipaque series had been treated with lithium which is known to produce severe and sometimes paroxysmal alterations of the EEG This particular patient was given supplementary diazepam (15 mg per os daily) for one week before, and 48 hours after, the examina-

tion, theoretically in an endeavour to raise the 'convulsion threshold' The lithium was withdrawn from 24 hours before, until 12 hours after, the myelography

All patients fasted for at least 4 hours before the myelography in order to reduce the risk of respiratory complications, should general anaesthesia prove necessary during or after myelography All patients were premedicated with 5 mg diazepam (Valium) intravenously immediately before the examination, 5 received an additional 30 mg of pentazocin (Fortalgesic) intramuscularly because of severe pain existing already before myelography, 2 further patients with an initial blood pressure below 100 mm Hg were given 0 5 mg of atropine intravenously

In the Amipaque series a maximum of 7 ml with a concentration of 200 mg I/ml was used, in the Dimer-X series 5 ml of the medium was diluted with 2 ml of spinal fluid, the two media thus had the same concentration of iodine per ml

The subarachnoid space was punctured at the level of L2–L3 or L3–L4 with a needle according to Stenstrom, OD 1 0 mm Three to 5 ml of CSF was withdrawn for laboratory examinations With the patient in the lateral position and with the head end of the examination couch elevated about 15° the contrast medium was injected slowly The cranial passage of the medium was followed by fluoroscopy, care being taken to avoid contact between the medium and the medullary cone, i e not to permit the contrast medium to extend above the lower margin of the first lumbar vertebra The amount of contrast medium used was always individualized, but usually the whole amount (7 ml) was used Films were obtained with the patient in lateral and prone position with the beam horizontal Both sides of the subarachnoid space were always examined on the same occasion In a few cases films were also taken with the patient standing If the contrast medium passed too high up the subarachnoid space during the examination, i e came into unquestionable contact with the medullary cone, repuncture was performed and a large part of the medium was withdrawn In addition 5 to 10 mg of diazepam was given intravenously every second hour for 6 hours after myelography In cases with only a brief or possible contact between the cone and the contrast medium, treatment was limited to additional diazepam intravenously

After myelography the patients were placed in a comfortable bed, with the trunk and head raised about 30° for 8 hours, and afterwards horizontal for a further 16 hours All patients spent at least 6 hours in the intensive care unit immediately following myelography During their stay there, one anaesthetist frequently checked the patellar tendon reflexes The patients were carefully observed for at least 3 days and any side effect was registered, except in 2 cases in the Amipaque series and 1 case in the Dimer-X series, where the patients were operated upon 48 hours after the myelography In most cases the patients were followed up for one week after myelography for any adverse reactions, if reactions occurred, the patients were kept under observation until the symptoms subsided

EEG recordings were obtained before and 3 hours after myelography, in 45 of the Amipaque cases and 41 of the Dimer-X cases an additional recording was made

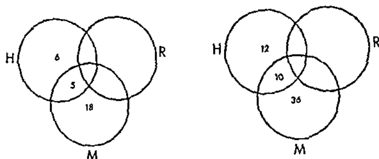


Fig 1 Immediate side effects in 50 cases, examined with Amipaque Left absolute figures. Right relative figures (per cent) H – hyperexcitation, R = radicular reaction, M = meningeal irritation

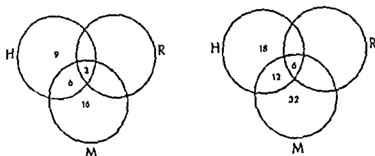


Fig. 2 Immediate side effects in 50 cases, examined with Dimer-X Left absolute figures, Right relative figures (per cent) H = hyperexcitation, R – radicular reaction, M = meningeal irritation

24 hours after the myelography In 5 cases in the Amipaque group further EEG recordings were made EEG was recorded with a 16-channel electroencephalograph, the 10–20 electrode system of the International Federation was used with longitudinal and transverse bipolar derivations Hyperventilation was performed only in connection with recording before myelography The recordings were classified according to customary visual technique For definitions of normal and pathologic findings reference is made to SELLDEN (1964), EEG-OLOFSSON et coll (1971) and PETERSÉN & EEG-OLOFSSON (1971)

Results

Immediate side effects appearing during or following lumbar myelography may be divided into three groups depending on the part of the nervous system irritated by the contrast medium (IRSTAM 1973) (1) Hyperexcitation (epileptic or clonic convulsions, fibrillations or fasciculations, increased patellar tendon reflexes), (2) Radicular reaction (hyperalgesia, pain in the abdomen, retention of urine) and (3) Meningeal irritation (cephalgia, nausea, rise in temperature with or without meningitis, meningism, fall in blood pressure)

Table 1

Frequency of headache following lumbar myelography with Amipaque or Dimer-X

	Amipaque		Dimer-X	
	Total	Relative	Total	Relative
Males	11/32	34 %	11/33	33 %
Females	6/18	33 %	8/17	47 %

In the present series side effects occurred in 29 cases (58 %) examined with Amipaque and in 34 (68 %) examined with Dimer-X, the distribution among the various groups is presented in Fig 1 (Amipaque) and Fig 2 (Dimer-X)

The hyperexcitation group contained no case of epileptic or clonic convulsions in either series Of 2 patients in the Dimer-X series, one developed small fasciculations in both legs 1 hour after the injection of the contrast medium, the other had fibrillations in one leg, starting one and a half hours after myelography These signs disappeared immediately after injection of diazepam

An increase in the patellar tendon reflexes was registered in 11 cases in the Amipaque series and in 18 cases in the Dimer-X series The patellar tendon reflexes were normal before and immediately following myelography Within 1 to 5 hours after myelography there was a definite uni- or bilateral increase in the patellar tendon reflexes

In the Amipaque series the reflexes were increased bilaterally in 8 cases and unilaterally in 3, the corresponding figures of the Dimer-X series were 11 and 7 Except for 2 Dimer-X cases, a unilateral increase in patellar tendon reflexes was always recorded on the side examined first, i e the side exposed to the highest concentration of the medium Patients with increased patellar tendon reflexes were treated immediately with 5 to 10 mg of diazepam intravenously or intramuscularly, or both, the reflexes became normal within a few minutes, but usually increased again within 2 to 4 hours, and injections of diazepam were repeated for up to 9 hours after myelography

None of the patients with increased patellar tendon reflexes in the Amipaque series had other adverse reactions during periods of hyperreflexia In 5 of the patients in the Dimer-X group other reactions were observed during periods of increased patellar tendon reflexes Two of these patients were the earlier mentioned cases with fasciculations or fibrillations Three patients had moderate headache and lumbosciatic pain, which was accentuated for about 24 hours after myelography, but the accentuation did not coincide with the periods with increased reflexes

All case reports were carefully scrutinized for pre-myelographic neurologic signs, pre-myelographic changes of the reflexes or motor function of the legs or function of the bladder recorded were evenly distributed among those with and without a

post-myelographic increase of the patellar tendon reflexes, irrespective of the type of contrast medium used

Headache was the most common adverse reaction with either of the media, it occurred in 17 cases (34%) of the Amipaque series and in 19 cases (38%) of the Dimer X series In both series the headache usually began within 3 to 6 hours of the examination and disappeared within 24 to 72 hours, however, in 2 cases of each series headache started 26 to 30 hours after the myelography and in a further patient examined with Amipaque headache began 48 hours following myelography In these 5 latter cases the headache continued for about 48 hours The headache was mild to moderate except in 2 patients of the Amipaque series They complained of a severe and intense pain, requiring bed rest—in one of them for 6 days, in the other for 10 days The pain gradually abated after 14 to 15 days The latter case was complicated for 6 days also by simultaneous meningism, i e stiff neck, but otherwise no clinical signs of meningitis Furthermore, EEG of that patient 24 hours after the myelography showed equivocal paroxysmal changes These changes will be commented upon in the section on EEG effects Headache was slightly more common in the women in the Dimer-X series than in the Amipaque series (Table 1)

An increase in body temperature by 1°C or more was recorded within 12 hours of myelography in 6 patients of the Amipaque series and in 7 of the Dimer-X series, the temperature fell to normal within 24 to 48 hours Simultaneous meningism was present in 1 Dimer-X patient One Dimer X patient had a temperature of 39 7°C 8 hours after myelography and had also headache and severe nausea but no stiffness of the neck In the CSF obtained at repuncture numerous multinuclear white blood cells were found, but no bacteria at direct microscopy, and culture gave no growth The temperature fell to normal within 24 hours and other symptoms abated within a further 24 hours The reaction was interpreted as a chemical meningitis and the patient received only symptomatic treatment

One patient in the Amipaque group developed a slight fall of the blood pressure 5 hours after myelography, the patient then had mild headache but no other side effects There were no signs of shock and the blood pressure was normalized by a single dose of 0 5 mg of atropine intravenously A moderate hypotension occurred immediately after lumbar puncture in 5 cases of the Amipaque series and in 4 of the Dimer X series The low blood pressure was corrected by 0 5 mg of atropine intravenously and no further hypotension was recorded

As judged from fluoroscopy and films, no contact occurred between the medium and the medullary cone in the Amipaque series In 4 Dimer-X cases the contrast medium passed into contact with the medullary cone during examination despite precautions Three of those patients were re punctured and 10 to 20 ml of CSF containing Dimer X was withdrawn, 5 mg of diazepam was injected intravenously every second hour for the following 6 hours In 2 of these patients no side effects or EEG abnormalities occurred, the third patient developed increased patellar tendon reflexes one and a half hours after repuncture and hyperreflexia disappeared promptly

Table 2

Age and sex distribution of cases, examined with Amipaque or Dimer X

Age	≤20	21–35	36–50	51–65	≥66
Amipaque					
Males	1	8	14	6	3*
Females	0	6	7*	4	1
Dimer-X					
Males	1	6	21	5	0
Females	0	4*	8	5	0

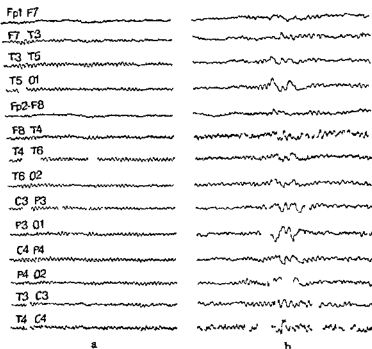
* One of the patients in this group was examined twice, in this table the patient was counted twice

after injection of diazepam In the fourth case the contrast medium reached the medullary cone for only such a short period that repuncture was considered unnecessary Only diazepam was given intravenously in the same way as in the other three cases No EEG alterations were noted 3 and 24 hours after the myelography However, patellar tendon reflexes increased just before the injection of diazepam at 4 hours after myelography Upon this injection reflexes were promptly normalized The patient complained of moderate headache and severe pain for 60 hours after myelography

EEG before myelography Myelography was always preceded by EEG, usually the day before The age and sex distribution of the patients of the series is given in Table 2 Nine (18 %) of the 50 patients of the Amipaque series had an abnormal EEG before myelography Except 1, these EEG were slightly abnormal with some increase of low frequency activity within the theta range No focal or paroxysmal abnormalities were noted The remaining case had a moderate increase of theta activity most prominent in the left fronto-temporal region Five (10 %) of the Dimer-X cases presented an abnormal EEG before myelography Four of these cases revealed slightly abnormal EEG findings comparable to those in the above mentioned Amipaque cases The fifth case exhibited a moderate amount of bursts of high amplitude (150 μV) 3 5 to 4 0 Hz waves bilaterally

EEG after myelography Three hours after myelography the EEG was unaltered in 46 (92 %) of the Amipaque cases, including 38 with a normal EEG and 8 cases with a slightly abnormal premyelographic EEG The 3-hour EEG was unaltered in 47 (94 %) of the Dimer-X cases including 43 with a normal, and 4 with a slightly abnormal, premyelographic EEG

Fig 3 a) Premyelographic recording Normal EEG b) 3 hours after myelography and 5 mg of ... lly c) 24 hours after myelography ... myelography and 3 hours after 5



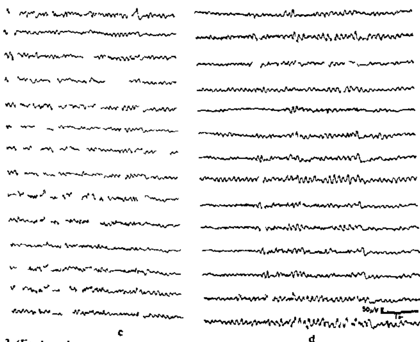


Fig 3 (For legend see oppos te page)

Compared with the premyelographic recordings, the EEG was altered at the 3 hour registration in 4 of the Amipaque cases, 3 with a primarily normal EEG and 1 with a primarily abnormal recording Such changes were also found in the 3 hour recording in 3 Dimer-X cases, 2 without and 1 with premyelographic abnormalities

In all 7 cases there was a slight to moderate increase of low frequency activity, mostly theta In 1 of the primarily normal Amipaque cases equivocal paroxysmal activity appeared bilaterally in short bursts (Fig 3) In one of the cases the recorded changes were ascribed mainly to drowsiness In the remaining 6 cases drowsiness was evident from the EEG, but it could not by itself account for the difference between the pre- and postmyelographic recordings

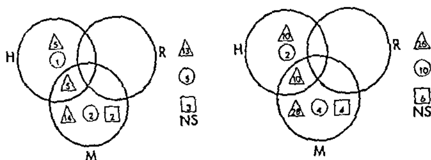
At the 24-hour recording equivocal paroxysmal activity of the same type as illustrated in Fig 3 was found in one of the Amipaque cases The pre-myelographic as well as the 3-hour EEG of that patient was normal At further control 72 hours after myelography the paroxysmal pattern had disappeared but low frequency activity was somewhat increased Four days after myelography EEG was normal At the 24-hour EEG the recordings of all the 7 patients with alterations at 3 hours appeared normal, and only exhibited signs of drowsiness In all the other cases the 24-hour recording did not differ from the initial one

When evaluating EEG effects possibly caused by the contrast medium, the simultaneous administration of diazepam might introduce a source of error In order to analyze the effects of diazepam selectively, EEG was repeated in 3 patients a few weeks after myelography Two of them belonged to the group with an equivocal paroxysmal abnormality, the third patient was one of the primarily normal ones with a moderate increase in low frequency activity at the 3 hour EEG control The procedure included EEG before, and 3 hours after, an intravenous injection of 5 mg of diazepam as in connection with lumbar myelography Some increase in low voltage low frequency activity denoting drowsiness was recorded in all the cases, but never burst activity or paroxysmal changes

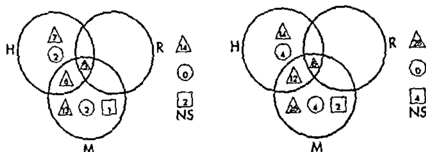
EEG abnormalities versus immediate side effects The 8 cases in whom the premyelographic EEG had changed 3 and 24 hours after myelography were evenly distributed between those with and without side effects irrespective of contrast medium used (Figs 4, 5) Thus, no correlation was found between clinical side effects and EEG findings in connection with lumbar myelography

Discussion

As in the previous material, the present patients were premedicated with diazepam In our opinion, this drug has a good sedative effect and in many cases temporarily reduces the lumbosciatic pain Diazepam also increases 'the convulsion threshold' and offers protection against seizures However, in order to ward off seizures completely, diazepam must be given in doses larger than those used as premedica-



after myelography



after myelography

tion Since the frequency of adverse reactions in the previous series premedicated with diazepam were few and as seizures did not occur in the last 600 of the Dimer-X cases, it was decided to use diazepam also in the present investigation in order to permit comparison of the results obtained in the previous series examined with Dimer-X (IRSTAM 1973, IRSTAM & SELLDÉN 1975)

Like all other drugs with a sedative effect, diazepam causes drowsiness which increases the amount of low frequency activity in the EEG. In addition, any existing EEG abnormality might be accentuated by drowsiness It should therefore be pointed out that the EEG changes described refer to the combined effect of the contrast medium and the premedication EEG was repeated in 3 cases in order to analyze the effects of diazepam selectively The recorded increase in low frequency activity 3 hours after injection of diazepam was much less evident than at myelography, the amount of low frequency activity was less and the amplitudes were smaller No burst

activity of equivocal paroxysmal type appeared The EEG changes noted at myelography could thus not be explained by diazepam per se The results suggest a causal connection between the EEG findings and the contrast medium used On the other hand, it should be pointed out that the EEG changes following lumbar myelography with Amipaque or Dimer-X were relatively discrete Some burst activity appeared in two Amipaque cases, but no evident spikes or sharp waves The burst activity in the EEG was of the same type as that described by GONSETTE (1973) at thoracic myelography with Amipaque The type of EEG abnormalities—bilateral synchronous burst activity—might suggest a subcortical origin The remaining 6 cases with abnormalities at the postmyelographic controls had more or less marked accentuation of theta activity, diffusely or slightly more on one side These changes were similar to those often seen at encephalography or cerebral angiography (e g RIEHL & ANSEL 1969, BINNIE et coll 1971)

HINDMARSH (1975 b) reported a total frequency of side effects of 62 8 per cent in a series of lumbar myelographies with Amipaque This frequency is equal to that recorded in the present Amipaque series (58 %) Adverse reactions to Dimer-X were more common in the series of HINDMARSH than in the present series (76 7 and 68 %, respectively) There are many differences between the present material and that of HINDMARSH In his series, the patients were not premedicated and the average amount of Amipaque and Dimer-X substantially exceeded that used in the present series The patients in HINDMARSH's series were not subjected to frequent reflex tests, as in our series, and no 3-hour EEG recordings were performed HINDMARSH interviewed every patient 22 to 26 hours after myelography according to a standardized scheme The patients in the present series were observed at the ward for usually one week where they were questioned and examined every day for side effects

Adverse effects were observed more often in the present Dimer-X series (68 %) than in two similar series reported by IRSTAM (1973) and IRSTAM & SELLDEN (1975) The parameter of increased patellar tendon reflexes was not included in the previous series, but even if such hyperreflexia is not included in the present series, the total frequency of side effects (54 %) by far exceeds earlier figures (28 3 % and 24 4 % respectively) The method of examination, after-care and collection of information concerning side effects were the same in all Dimer-X series One possible explanation of differences of side effects in the Dimer-X series might be differences between batches of the medium used The batch of Dimer-X used by HINDMARSH was the same as that used in the present series, but different from those in the previous series

No seizures occurred in the present series In 2 of the Dimer X patients fibrillations or fasciculations occurred 60 to 90 minutes after the myelography This reaction was accompanied by an increase in the tendon reflexes No hyperexcitation signs were encountered in the Amipaque series Fibrillations or fasciculations of the legs are rare and did not occur at any of the last 600 Dimer-X myelographies Neither were generalized seizures or myoclonic spasms observed in these cases This might be compared with 2 cases of myoclonic spasms and 1 case of grand mal seizures at 34

Dimer X myelographies in HINDMARSH's series The only important difference in performance between HINDMARSH's Dimer X series and the present and previous series is that HINDMARSH used large amounts of Dimer X, several times exceeding the recommended maximum dose In our opinion this implies that by exceeding the recommended maximum dose of 5 ml of Dimer X the risks of serious complications increase considerably No such relationship between frequency of side effects and amount of Amipaque has yet been reported

In the continual search for hyperreflexibility of the legs the patellar tendon reflexes were examined frequently throughout the stay in the intensive care unit and by the same anaesthetist Hyperreflexia of the legs was less common (22%) in the Amipaque series, than in the Dimer X series (36%) Hyperreflexia was slightly more common in the women than in the men in the Dimer X series (47% compared with 30%) but in the Amipaque series it was equally common in both sexes In the two series of HINDMARSH (1973 1975 b) and of SKALPE et coll (1973) reflex tests were not performed repeatedly during the first 6 to 8 hours after myelography In one of HINDMARSH's series (1975 a) EMG recordings with surface electrodes were performed up to 20 minutes after injection of Amipaque, but not later In the present series hyperreflexia never occurred before at least 1 hour after myelography Hence, an increase in the tendon reflexes in the series of HINDMARSH and SKALPE et coll might have occurred without having been observed In the present series hyperreflexia occurred without any correlation to other side effects and the patients were not aware of the increased reflexes We regard hyperreflexia of the legs as a sign of irritation elicited by the contrast media probably at a spinal level

SUMMARY

The adverse effects in a series of 50 lumbar myelographies with Amipaque were compared with those in a corresponding series examined with Dimer X Side effects occurred in 58% of the cases examined with Amipaque and in 68% of the Dimer X series No seizures occurred in either series but slight fibrillations or fasciculations appeared in 2 Dimer X patients Hyperreflexia of the legs was recorded in 22% of the Amipaque and in 36% of the Dimer X cases Other adverse reactions to the media were mild to moderate Some burst activity, but no definite paroxysmal abnormality was noted in EEG recordings in 2 Amipaque cases The low epileptogenicity of Amipaque has ensured a wider safety margin of lumbar myelography

ZUSAMMENFASSUNG

Die nachteiligen Effekte von Amipaque wurden in einer Serie von 50 lumbalen Myelographien mit denen in einer entsprechenden Serie bei der Dimer X verwendet wurde verglichen Nebeneffekte traten in 58% der mit Amipaque und in 68% in der mit Dimer X untersuchten Fälle auf Bei keiner der Serien traten Krampfe auf jedoch leichte Fibrillationen oder Fasciculationen bei zwei Dimer X Patienten. Hyperreflexie der Beine wurde in 22% der mit Amipaque und 36% der mit Dimer X untersuchten Fälle registriert Andere

activity of equivocal paroxysmal type appeared The EEG changes noted at myelography could thus not be explained by diazepam per se The results suggest a causal connection between the EEG findings and the contrast medium used On the other hand, it should be pointed out that the EEG changes following lumbar myelography with Amipaque or Dimer-X were relatively discrete Some burst activity appeared in two Amipaque cases, but no evident spikes or sharp waves The burst activity in the EEG was of the same type as that described by GONSETTE (1973) at thoracic myelography with Amipaque The type of EEG abnormalities—bilateral synchronous burst activity—might suggest a subcortical origin The remaining 6 cases with abnormalities at the postmyelographic controls had more or less marked accentuation of theta activity, diffusely or slightly more on one side These changes were similar to those often seen at encephalography or cerebral angiography (e g RIEHL & ANSEL 1969, BINNIE et coll 1971)

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nachteilige Reaktionen gegenüber den Mitteln waren leicht bis mässig Bei den EEG Registrierungen wurden bei zwei Amipaque-Fällen eine gewisse Entladungsaktivität, jedoch keine paroxysmale Abnormität festgestellt Die niedrige epileptogene Eigenschaft von Amipaque hat zu einer grosseren Sicherheits-Marginale bei der lumbalen Myelographie geführt

RÉSUMÉ

Les auteurs ont comparé sur 2 séries de myélographies lombaires les effets nuisibles de l'Amipaque et du Dimer X Ie y a eu des effets secondaires dans 58 % des cas examinés par l'Amipaque et dans 68 % des cas examinés par le Dimer X Il n'y a pas eu de crise convulsive dans aucune des séries mais il y a eu des légères fibrillations ou fasciculations chez 2 malades examinés par le Dimer X On a constaté une hyperréflexie des membres inferieurs dans 22 % des cas examinés par l'Amipaque et dans 36 % avec le Dimer X Les autres effets nuisibles de ces moyens de contraste ont été légers ou modérés Chez 2 malades examinés par l'Amipaque les enregistrements E E G ont montré une certaine activité en bouffées mais pas d'anomalie paroxystique nette Le faible pouvoir épileptogène de l'Amipaque augmente la marge de sécurité de la myélographie lombaire

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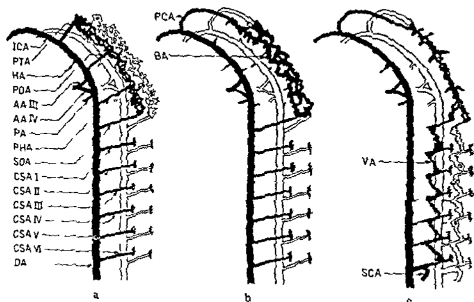


Fig 1 Simplified presentation of development of vertebro-basilar arterial system ...
AA III and IV = 3rd and 4th ac ...
intersegmental arteries I VI ...

... and PTA BA in formation c) 7 to 12 mm embryo VA in formation through transverse anastomoses between SOA and SCA I VI

lifetime of the primitive trigeminal, otic, and hypoglossal arteries *is thus less than a week*

As early as 1844 QUAIN described a persistent trigeminal artery found at autopsy and in 1889 *BATUJEFF* reported a persistent hypoglossal artery Single cases were then reported *by several authors*, but it was not until the introduction of cerebral angiography *that clinical* series large enough to allow an estimation of the frequency of these arteries *became available The first* angiographic report on a persistent trigeminal artery *was published* by SUTTON (1950), and in the same year LINDGREN presented a case *with a persistent hypoglossal* artery From large angiographic materials the frequency *of a persistent* trigeminal artery has been estimated at 0 1 to 0 2 per cent, *while in all only 25 persistent* hypoglossal arteries have been *reported* No convincing report of a persistent *otic artery has* yet been published A detailed review of these anomalous carotid *basilar anastomoses* has been made by LIE (1968)

The persistent trigeminal *artery corresponds* in its course to the primitive trigeminal artery It leaves the internal *carotid artery* where this enters the cavernous sinus and passes posteriorly to join the *basilar artery*, normally between the origins of the superior cerebellar and *anterior inferior* cerebellar arteries (Fig 2)

FROM THE SECTION ON NEURORADIOLOGY (DIRECTOR S CRONQVIST), DEPARTMENT O
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PERSISTENT HYPOGLOSSAL ARTERY, DIAGNOSTIC CRITERIA

Report of a case

JAN BRISMAR

The origin of the vertebro-basilar system is embryologically complex Extensive dissections were made by PADGET (1948, 1954) and form the basis for the following description In the 4 to 5 mm long (crown-rump length) human embryo (ovulation age 29 days), bilateral longitudinal neural arteries have just developed in the hind brain region (Fig 1 a) At this stage these arteries are supplied cranially by the primitive trigeminal arteries and caudally by the suboccipital intersegmental arteries Two transitory branches from the paired aorta, the primitive otic artery and the primitive hypoglossal artery, also contribute By the time the embryo is 5 to 6 mm long (Fig 1 b), the posterior communicating artery has already developed and taken over the function from these temporary, primitive arteries, which then rapidly degenerate and disappear, the otic artery first, followed by the hypoglossal and trigeminal arteries At the same stage the longitudinal neural arteries start to fuse, forming the basilar artery During the 7 to 12 mm stage (ovulation age 32 days), the vertebral arteries are formed from transverse anastomoses between adjacent cervical intersegmental arteries, beginning with the suboccipital intersegmental artery and proceeding downwards to the 6th cervical intersegmental artery, which forms the origin of the adult vertebral artery and the subclavian artery (Fig 1 c) The normal

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Fig 4 Angiography of hypoglossal artery a) Lateral view Filling of carotid siphon through posterior communicating artery (←) b) A p view Retrograde filling of hypoplastic vertebral arteries (←→)

The persistent hypoglossal artery is not identical with its primitive precursor in the *embryo* While the latter artery passes medially and anteriorly to the roots of the hypoglossal nerve the persistent hypoglossal artery runs posteriorly and laterally to the nerve Furthermore the posterior inferior cerebellar artery may have its origin in the persistent hypoglossal artery although in the embryo it originates in the lateral anastomotic channel (a transient communication between the basilar artery and the developing vertebral artery) These facts led MORRIS & MOFFAT (1956) to suggest that the cranial part of the persisting hypoglossal artery was formed by the lateral anastomotic channel connected to the basal artery through a transverse anastomotic channel

Case report

A 56-year-old woman with a history of migraine was referred for angiography after a grand mal seizure followed by a transient right sided hemiparesis

Left common carotid angiography No pathology or anomaly in the region of the carotid bifurcation or in the cervical part of he
communicating artery the anterior
after compression of the contralat-
was found supplied by the anterior
right carotid angiography

P nh
at t



Fig 2 Internal carotid angiography, lateral view Persistent primitive trigeminal artery



a



b

Fig 3 Right common carotid angiography a) Lateral and b) a p views Persistent hypoglossal artery (→)



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Case report

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Left common carotid angiography No pathology or anomaly in the region of the carotid bifurcation or in the cervical part of the internal carotid artery was present The posterior communicating artery, the anterior cerebral and the pericallosal arteries did not fill even after compression of the contralateral carotid artery A large frontal falx meningeoma was found supplied by the anterior falx branch of the ophthalmic artery which motivated right carotid angiography

Right common carotid angiography Direct puncture The carotid bifurcation was situated at the C4 level Two cm cephalad to the bifurcation, a wide artery branched off from the

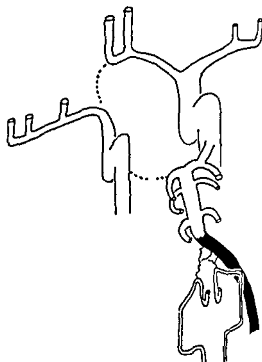


Fig 5 Composite drawing of the angiographic findings Persistent hypoglossal artery (black) Dashed lines indicate underdeveloped left sided anterior cerebral and posterior communicating arteries

internal carotid artery (Fig 2) This anomalous artery ran dorsally to the internal carotid artery in cephalad direction, passed through the anterior condyloid foramen, and ended at the basilar artery

Selective angiography of this anomalous artery Through a network, probably involving the posterior inferior cerebellar arteries, retrograde filling was obtained of both vertebral arteries (Fig 3) The vertebral arteries were hypoplastic and not filled peripherally to the origin of the posterior inferior cerebellar arteries The retrograde filling of the vertebral arteries was obtained only after selective injection into the anomalous artery and not after common carotid injection The contrast medium disappeared first from the caudal parts of the vertebral arteries, thus indicating a normal antegrade flow of blood in these arteries Good filling was achieved of the right internal carotid siphon and its intracranial branches through a wide posterior communicating artery on the right side

Right internal carotid angiography Both pericallosal arteries as well as the posterior cerebral arteries filled via the wide posterior communicating artery (Fig 4)

Right external carotid angiography No developmental anomalies
The patient refused permission for aortocervical angiography

Discussion

The following four criteria for the diagnosis of a primitive hypoglossal artery have been suggested by LIE, and have been accepted by DEBAENE et coll (1972) and HUBER & RIVOIR (1974) (1) The artery arises in the cervical region at the level of C1 to C3 as a robust branch from the internal carotid artery (2) After a somewhat

tortuous course, the artery proceeds through the anterior condyloid foramen (the hypoglossal canal) to the posterior cranial fossa It does not pass through the foramen magnum (3) The basilar artery is filled only beyond the point of junction with the anastomosis (4) The posterior communicating arteries are absent (i e are not visible on the films)

As evident from the case report, which describes beyond doubt a persistent hypoglossal artery, all of these criteria are not always fulfilled While the first two criteria are strictly anatomic, i e related to the course of the artery, the last two are related to theories concerning the cause of the anomaly Admittedly, in the light of embryology, it seems logical that hypoplasia of the posterior communicating arteries should be a necessary prerequisite for the persistence of the primitive hypoglossal artery This is also in concordance with the observations of PADGET (1948) concerning the primitive trigeminal artery She found that in embryos, postponed regression of this artery was correlated to delayed development of the posterior communicating artery

In the present case (Fig 5) a possible explanation for the persistence of the primitive hypoglossal artery may be that in early embryologic life the hypoplasia of the left anterior cerebral, and probably also of the left posterior communicating artery, put too hard a strain on the right internal carotid artery to allow it (through the right posterior communicating artery) to take over the role of the primitive arteries in supplying the hindbrain Neither could the role of these arteries be taken over by the hypoplastic vertebral arteries

Conclusion One new case with a persistent primitive hypoglossal artery indicates the necessity for revising the previous criteria used for diagnosing the anomaly

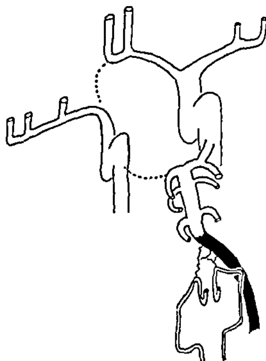
The following criteria only are suggested (1) A persistent primitive hypoglossal artery should leave the internal carotid artery as an extracranial branch (2) It should pass through the anterior condyloid foramen before joining the caudal part of the basilar artery

SUMMARY

After a brief recapitulation of the embryology of the vertebrobasilar arterial system, one new case (the 26th) with a persistent primitive hypoglossal artery is presented As in this case a well developed posterior communicating artery existed, new diagnostic criteria have been formulated

ZUSAMMENFASSUNG

Nach einer kurzen Rekapitulation der Embryologie des vertebrobasilaren arteriellen Systems wird ein neuer Fall (der 26) mit einer persistierenden, primitiven Hypoglossus-Arterie vorgestellt Da bei diesem Fall eine gut entwickelte A communicans post vorhanden war, wurden neue diagnostische Kriteria formuliert



anterior cerebral and posterior communicating arteries

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RÉSUMÉ

Après un bref rappel de l'embryologie du système artériel vertébro basilaire, l'auteur présente un nouveau cas (le 26°) d'artère hypoglosse primitive persistante Etant donné qu'il y avait dans ce cas une artère communicante postérieure bien développée, l'auteur a formulé de nouveaux critères diagnostiques

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SPINAL CORD VASCULARITY

II Extraspinal sources of spinal cord arteries in the rat

LEON TVETEN

The main purpose of the present series of investigations of the spinal cord vascularity was to obtain a basis allowing an estimate of functional disturbances following injury of arteries of the spinal cord A thorough knowledge of the anatomy of the vascular supply is then a prerequisite, and previously (TVETEN 1976 a) conditions in man were reported

Evaluation of the dynamics of cord dysfunction necessitates animal experiments Rats were chosen because GREENE (1959) reported a close similarity of the vascularity in rat and man Admittedly, only the larger aortic branches were described, while the arrangement of arterial tributaries to the spinal cord were not recorded in sufficient detail for experimental application Therefore, a detailed investigation of the extraspinal arteries and potential collateral pathways regarding the spinal cord circulation in the rat was performed

Material and Methods

The material included a total of 115 rats of both sexes, 72 were adults and 43 young or newborn rats belonging to eight litters Each litter comprised 3 to 7 animals and the age ranged from 1, 2 and 4 days to 1, 2, 4, 6 and 8 weeks The vascular system

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in rats is considered fully developed already at 13 to 15 days of fetal life (MOFFAT 1957)

Injection technique Heparin (50 units/100 g body weight) and Pentobarbital sodium (Nembutal, Abbott, 3 3 mg/100 g body weight) was administered into the peritoneal cavity About half an hour later injection of the contrast medium was performed by the method of CAMMERMEYER (1960), except that in adult animals, the injection pressure was controlled by a manometer connected to the injection tube The animals died during or immediately after the contrast injection

A warm (37 to 38°C), 80 or 50 % aqueous suspension of coloured contrast medium (Chromopaque Blue, Damancy & Co Ltd , England) with 4 % formalin and 10 % gelatine, kept in a water bath on a magnetic stirrer, was used to demonstrate the vessels The viscosity of the 80 % suspension as a rule prevented penetration of the capillary network The injection pressure was kept at 120 to 130 mm Hg and the procedure was usually accomplished in 10 to 15 min A blue discoloration of the mouth and eyes was a reliable indication of adequate filling of the vascular system Three to four ml of the contrast medium was sufficient to fill the arteries in adult animals

Following the injection the skin and the viscera were removed while the aorta and its main branches were kept intact with the specimen and placed in a solution of 10 % formalin and physiologic saline overnight Thereafter the specimen was processed for radiography and stereomicroscopy as previously described (TVETEN 1976 a)

The tube with a focal size of 0 4 mm × 8 mm was run at 20 to 35 kV, 15 to 25 mA for 20 to 30 min, FFD 25 to 150 cm, all adjusted to the thickness of the specimen

Results

The main sources of blood supply to the spinal cord of the rat may be divided into two groups The subclavian-vertebral system supplies the cervical cord and the upper 3 or 4 segments of the thoracic cord The descending aorta supplies the remaining part of the cord and the cauda equina by way of the aortic intercostal, the subcostal, the lumbar and the sacral arteries The lumbar and sacral arteries are mainly distributed to the nerve roots and the dorsal root ganglia of the cauda equina

The origin, course and branching of the vertebral artery in the rat to a large extent corresponds to conditions in man (Fig 1)

The arrangement of the spinal branches, however, differs somewhat in the two species In the rat the vertebral artery supplies regular branches to all intervertebral foramina of the cervical region, frequently even to the one between the seventh cervical and the first thoracic vertebra (Fig 2) Contrary to conditions in man, no additional branches from other neck arteries enter the foramina

The spinal branches of the cervical region in the rat divide and interconnect in a manner similar to that in man, i e small branches from each artery anastomose with

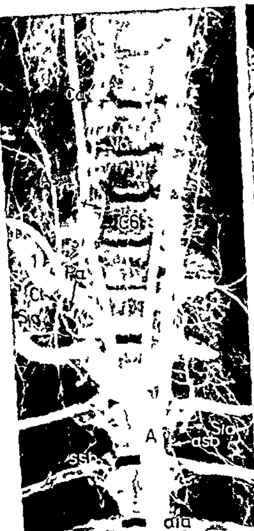


Fig 1



Fig 2

Descend ng aorta (A) Carotid
t) Deep
posterior
ebral ar

Fig. 2 Transparent specimen of cervical region photography Orig n of root arteries (r) all derived from the vertebral artery (Va) even that at C8 segment (rC8) Spinal cord (Sc) ventral (asa) and dorsal (psa) sp nal arteries

sim lar branches from above and below as well as with branches from the opposite side These interconnections form transverse and longitudinal anastomotic chains being most evident on the dorsal surface of the vertebral bodies Additional transverse connections are also formed by small penetrating twigs inside the vertebral bodies



Fig 3

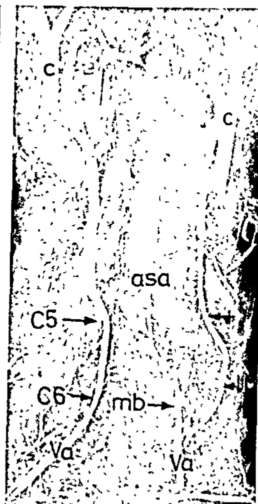


Fig 4

Fig. 3. Angiography Hypoplastic right vertebral (Va) artery. Basilar artery (Ba).

Fig. 4. Angiograph
runs along the C7
entering the verteb
the spinal canal at

The lateral segmental branches of the vertebral artery ramify into the deep muscles of the neck and connect with branches of other neck arteries

The incidence of extracranial variations of the vertebral artery was unexpectedly high. A hypoplastic vertebral artery similar to that in man occurred in about 8 per cent (9 of 115) of the animals, and twice as often on the left as on the right side (Fig. 3).

In one specimen the left vertebral artery divided close to its origin into a small medial branch which entered the transverse foramen of the sixth cervical vertebra, and a large lateral branch extending to the fifth vertebra before it traversed the foramen (Fig. 4). In another specimen the same condition existed except that the two branches arose separately from the left subclavian artery. In a third specimen the

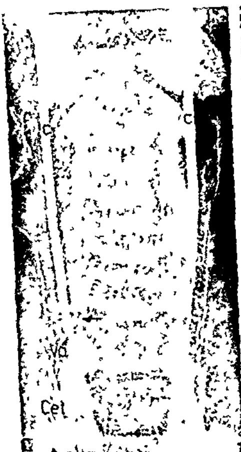


Fig 5

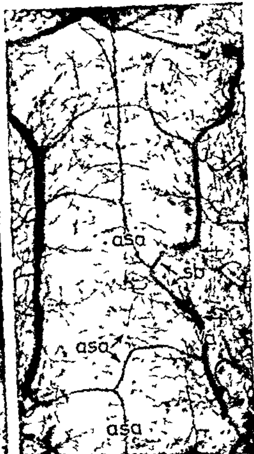


Fig 6

Fig 5 Angiography Right vertebral artery (Va) branching from the cervical trunk (Cet) to enter the transverse foramen of the fifth cervical vertebra (→) Common carotid artery (C)

right vertebral artery branched off from the cervical trunk (which corresponds to the thyreocervical trunk in man) and entered the transverse foramen of the fifth cervical vertebra (Fig 5)

The most common variation was a segmental anomaly of the cervical part of the vertebral artery, usually at C4 or C5 and predominantly on the left side (Fig 6) The anomaly was observed in about 17 per cent of the cases (9 adults and 11 youngsters) and consisted either of a complete interruption of the artery or in a displacement into the vertebral canal In the latter case the artery extended one or two segments along the lateral surface of the cervical cord outside the dura mater (Figs 1, 4)

At the upper or the lower end of the defect the artery usually connected with the ventral spinal artery by way of radicular arteries, thus forming a large intraspinal pathway between the two broken parts of the vertebral artery (Fig 7) Occasionally, a similar but less evident connection existed immediately outside the vertebral canal formed by the lateral segmental branches (Fig 7) The transverse foramen of the cervical vertebra at the site of the interrupted or displaced artery was usually absent At the upper end of the atlas the defective artery sometimes disappeared into the suboccipital region leaving no or only a tiny twig to join the intracranial part of the opposite vertebral artery (Fig 7)

The ascending cervical artery arose from the cervical trunk which according to GREENE corresponds to the thyreocervical trunk in man The artery soon divided into 2 or 3 branches (Fig 1) The larger of these extended in front of the transverse processes of the cervical vertebrae from C6 or C7 to C2 or C3 giving off branches to the muscles and the nerve trunks, in addition to tiny connections with the lateral branches of the vertebral artery Contrary to the situation in man, no significant branch from the ascending cervical artery in the rat entered the intervertebral foramina of the cervical region

The costocervical trunk in the rat gave rise to the deep cervical artery and the superior intercostal artery (Fig 1) The former, often small-sized and difficult to identify, gave off spinal branches to the intervertebral foramen between the seventh cervical and the first thoracic vertebra but no significant spinal cord feeder was ever observed arising from this artery It disappeared into the muscles at the back of the neck connecting with branches of other arteries in the neck

The superior intercostal artery in the rat was a conspicuous vessel distributing a series of branches to the upper four intercostal spaces on the right side, less constantly the upper three only on the left side (Fig 1) The mode of branching and the number of spaces supplied by the artery, however varied somewhat in individual cases consistent with variations in the arrangement of the upper aortic intercostal arteries (see below)

The spinal arteries of the costocervical trunk divided and interconnected in a manner similar to that of the spinal branches of the vertebral artery, but they rarely gave rise to significant root arteries extending to the surface of the cord In fact, as emphasized in another report (TVETEN 1976 b), the poor supply of the upper thoracic cord was closely related to a scanty regional distribution of the costocervical trunk

The most common arrangement of the aortic intercostal arteries was nine arteries on the left side and eight on the right They were distributed from the left fourth and the right fifth to the twelfth spaces and divided into one ventral and one dorsal branch A large number of the animals, however, displayed variations in the origin and the branching of the vessels in the upper part of the thoracic cavity Thus, in



Fig 7

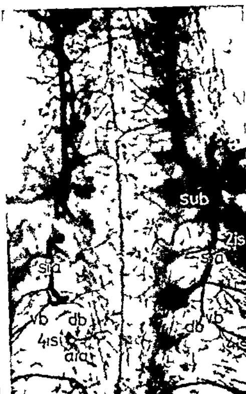


Fig 8

about 20 per cent (22 of 115) of the specimens the third intercostal artery on the left side branched off from the aorta In about half of these cases however the aortic segmental artery was represented by its proximal part plus the dorsal branch only the ventral branch being supplied by the superior intercostal artery (Fig 8) The same feature was recorded in the left fourth intercostal space in about 25 per cent of the specimens both in the left fourth and the third spaces in about 5 per cent of the cases On the right side similar variations confined to the fourth intercostal space were found in four animals only Finally 2 animals revealed aortic intercostals symmetrically arranged from the fifth to the twelfth spaces

At the upper or the lower end of the defect the artery usually connected with the ventral spinal artery by way of radicular arteries, thus forming a large intraspinal pathway between the two broken parts of the vertebral artery (Fig 7) Occasionally, a similar but less evident connection existed immediately outside the vertebral canal formed by the lateral segmental branches (Fig 7) The transverse foramen of the cervical vertebra at the site of the interrupted or displaced artery was usually absent At the upper end of the atlas the defective artery sometimes disappeared into the suboccipital region leaving no or only a tiny twig to join the intracranial part of the opposite vertebral artery (Fig 7)

The ascending cervical artery arose from the cervical trunk which according to GREENE corresponds to the thyreocervical trunk in man The artery soon divided into 2 or 3 branches (Fig 1) The larger of these extended in front of the transverse processes of the cervical vertebrae from C6 or C7 to C2 or C3 giving off branches to the muscles and the nerve trunks, in addition to tiny connections with the lateral branches of the vertebral artery Contrary to the situation in man, no significant branch from the ascending cervical artery in the rat entered the intervertebral foramina of the cervical region

The costocervical trunk in the rat gave rise to the deep cervical artery and the superior intercostal artery (Fig 1) The former, often small-sized and difficult to identify, gave off spinal branches to the intervertebral foramen between the seventh cervical and the first thoracic vertebra but no significant spinal cord feeder was ever observed arising from this artery It disappeared into the muscles at the back of the neck connecting with branches of other arteries in the neck

The superior intercostal artery in the rat was a conspicuous vessel distributing a series of branches to the upper four intercostal spaces on the right side, less constantly the upper three only on the left side (Fig 1) The mode of branching and the number of spaces supplied by the artery, however, varied somewhat in individual cases, consistent with variations in the arrangement of the upper aortic intercostal arteries (see below)

The spinal arteries of the costocervical trunk divided and interconnected in a manner similar to that of the spinal branches of the vertebral artery, but they rarely gave rise to significant root arteries extending to the surface of the cord In fact, as emphasized in another report (TVETEN 1976 b), the poor supply of the upper thoracic cord was closely related to a scanty regional distribution of the costocervical trunk

The most common arrangement of the aortic intercostal arteries was nine arteries on the left side and eight on the right They were distributed from the left fourth and the right fifth to the twelfth spaces and divided into one ventral and one dorsal branch A large number of the animals, however, displayed variations in the origin and the branching of the vessels in the upper part of the thoracic cavity Thus, in



Fig 10 Angiography Arteries of the lower lumbar and sacral region in the rat The fifth pair of lumbar arteries (5La) arises from the aorta (A) while the sixth pair of lumbar arteries (6La) and the paired sacral arteries (1Sa 3Sa) arise from the median sacral artery (Ma) The exact origin of the sixth pair of lumbar arteries is clearly visible in lateral position of the specimen only Bifurcation of the aorta (A) into the common iliac arteries (Cia) at the border between the sixth lumbar (L6) and the first sacral (S1) vertebral bodies Ileolumbar arteries (Ia)

specimens Characteristically, a significant tributary to the cord was never found originating from such a rudimentary subcostal artery

Of the 6 pairs of lumbar arteries, the upper five arose from the dorsal aspect of the aorta while the sixth pair came from the median sacral artery (Figs 9, 10) The spinal branch of the latter passed through the foramen between the sixth lumbar and the first sacral vertebrae Only the upper 2 or 3 pairs of the lumbar arteries contributed to the supply of the spinal cord (TVETEN 1976 b) The other root arteries of the lumbo sacral region terminated mainly on the nerve roots and the dorsal root ganglia However in the lumbo-sacral region a number of dorsal root arteries created evident anastomoses with central branches of the ventral spinal artery (described in more detail in another report TVETEN 1976 b)

The median sacral artery originated from dorsal aspect of the terminal part of the aorta at the level of the fifth or the sixth lumbar vertebra and extended into the tail

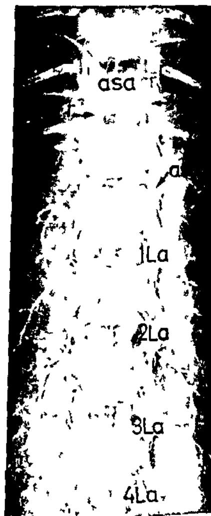


Fig 9 Angiography The arrangement of extraspinal arteries in the lower thoracic and the upper two thirds of the lumbar region The left aortic subcostal artery (asuba) furnishes the dorsal branch only the ventral branch (vbr) being supplied by the twelfth intercostal artery (12ia) Ventral root arteries (r) arising from the left twelfth intercostal artery and the right subcostal artery to join the ventral spinal artery (asa) are discernible The upper four lumbar arteries (1La–4La)

Most of the ventral feeders of the upper thoracic cord follow the left Th3 nerve root (TVETEN 1976 b) The vast majority of these vessels originates from the aortic intercostals In 2 cases only a significant ventral feeder of the third thoracic segment of the cord could be traced back to the spinal branch of the superior intercostal artery This observation supports the view that the costocervical trunk is of minor importance regarding the spinal cord circulation in rats

The subcostal artery in the rat is the most important branch of the thoracic aorta *because it frequently distributes large tributaries to the spinal cord, i e* the great ventral radicular artery (TVETEN 1976 b) It runs along the lower border of the thirteenth rib and, as a rule, divides in the same way as the aortic intercostals However, in about one-third (36/115) of the specimens the proximal part plus the dorsal branch only of the segmental artery was present while the ventral branch was supplied by the last intercostal or, occasionally, by the first lumbar artery (Fig 9) This occurred twice as often on the left as on the right side, bilaterally in about 5 per cent of the

these also being similar to those observed in man, such as different width of the two arteries, hypoplasia and abnormal origin or site of entrance into the cervical spine The major abnormality, however, which does not seem to have been previously described in man or in experimental animals was a segmental defect or displacement of parts of the vertebral artery This peculiar anomaly can be explained from developmental features of the brachiocephalic arteries in rats MOFFAT (1957, 1961) states that the vertebral artery is formed by fusion of longitudinal anastomoses between the postcostal branches of the primitive intersegmental arteries Evidently, when such anastomoses fail to develop, a defect involving one or more segments of the artery will ensue

The superior intercostal artery of the costocervical trunk is more prominent in the rat than in man, though GREENE believes that in the rat this artery supplies only the upper three intercostal spaces, and on the left side frequently the first and the second spaces only She also believes that separate origins of the ventral and dorsal branches of the left third and the fourth intercostal artery occur in about two thirds of the specimens The dorsal branch is then supplied by the aorta, the ventral one by the superior intercostal artery Such variations were less frequently observed in the present material and in the vast majority of the rats the superior intercostal artery distributed a series of regular branches to the upper three intercostal spaces on the left side and the upper four on the right side This is important to consider because of the paucity of significant spinal tributaries to the upper thoracic cord, described in closer detail in another report (TVETEN 1976 b)

The poor supply of spinal feeders to the upper three or four thoracic segments of the cord in individual cases was closely related to the regional distribution of the superior intercostal artery Thus, with regard to the spinal cord circulation in rats, the costocervical trunk seems merely to serve as an anastomotic link between the vertebral artery above and the aortic intercostals below by way of intra- as well as extraspinal connections between these arteries

In accordance with the arrangement of the superior intercostal artery and the fact that the rat possesses thirteen thoracic vertebrae, the most common number of the aortic intercostal arteries is nine on the left side and eight on the right side [illegible]

[illegible] aortic subcostal artery was remarkable considering the frequent occurrence of important spinal cord tributaries (the great ventral radicular artery, or Adamkiewicz' artery) arising from the subcostal space of the rat (TVETEN 1976 b) It was found, however, that an aortic subcostal artery with no ventral branch rarely gave rise to spinal cord tributaries, a feature probably reflecting a natural protective means (TVETEN 1976 a)

GREENE described five pairs of lumbar segmental arteries in the rat, the upper four arising from the dorsal aspect of the aorta while the fifth pair branched off from the



Fig 11 Transparent specimen photography Dorsal view of the lumbar region with intact spinal cord in a decalcified specimen Tiny extraspinal connections between adjacent lumbar arteries (→)

(Fig 10) It gave rise to segmental arteries which distributed spinal branches to the sacral region

The ileolumbar arteries in the rat were constant branches of the lumbar aorta, though the origin varied somewhat on the two sides (Fig 10) However, no evident spinal branch was ever observed originating from these arteries

At each level of the thoracic, lumbar and sacral regions tiny branches from the segmental arteries interconnected inside as well as outside the vertebral canal in a manner similar to that in man (Fig 11) As in man evident anastomoses were found between the aortic segmental arteries and the internal mammary artery, and between the inferior and the superior epigastric arteries, respectively

Discussion

The anatomic arrangement of the main sources of spinal cord arteries in the rat resembles that in man However, important differences exist Thus, in the rat the vertebral artery appears to be the sole source of blood supply to the cervical cord Contrary to the situation in man, no additional branches from other arteries in the neck enter the intervertebral foraminae of the cervical region in the rat

A high incidence of variations of the vertebral artery existed in the rat, some of

Beim Menschen besteht die wesentliche Abweichung in zwei oder mehr Intercostal Arterien, die von einem gemeinsamen Stamm ausgehen, wahrend die Ratte häufiger eine rudimentären subcostale Arterie aufweist Schliesslich sind die ileo lumbal Arterien bei der Ratte konstante Äste der lumbalen Aorta Trotz dieser Unterschiede in der vaskularen Anatomie scheint die Ratte gut geeignet fur vergleichende experimentelle Untersuchungen zu sein, die beim Menschen nicht vorgenommen werden konnen

RESUMÉ

La disposition des sources extra vertebrales des artères de la moelle chez le rat est semblable à celle de l homme Cependant certaines differences existent, concernant surtout la disposition des branches spinales fournies par les artères sous-clavières vertebrales A la difference de ce qui se passe chez l homme l artère vertebrale du rat parait être la seule source d irrigation sanguine de la moelle cervicale Il y a de nombreuses variations ou anomalies de l artere vertébrale chez le rat Les variations vasculaires des espaces thoraciques supérieurs gauches sont frequentes chez le rat et plus compliquees que chez l homme Dans ces deux espèces, l auteur a trouve une faible irrigation d importants vaisseaux nourriciers de la moelle provenant de l artère intercostale supérieure du tronc costocervical Des variations de l origine et de la ramification des arteres segmentaires arterielles se produisent dans ces 2 espèces Chez l homme la variation principale consiste dans l origine par un tronc commun de 2 ou plusieurs artères intercostales alors que le rat a plus souvent une artère sous-costale rudimentaire Enfin, les artères ilio lombaires du rat sont des branches constantes de l aorte lombaire Malgré ces differences dans l anatomie vasculaire le rat paraît convenir pour des recherches experimentales comparatives qui ne peuvent pas être faites chez l homme

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TVETEN L (a) S[illegible] cord arteries in man Act[illegible]

— (b) [illegible] To be published in Act[illegible] [illegible]osis 17 (1976)

median sacral artery Moreover, this author claimed that the ileolumbar arteries not infrequently arise from the common iliac arteries and supply spinal branches to the intervertebral foramen between the last lumbar and the first sacral vertebrae BRAITHWAITE (1954) in a schematic drawing also depicted only five lumbar segmental arteries although segmental branches from the median sacral artery entering the vertebral canal between the sixth lumbar and the first sacral vertebrae are clearly visible in his angiographic illustrations In the present material the ileolumbar arteries were constant branches of the lumbar aorta and contrary to those in man, they never supplied significant branches to the spinal canal

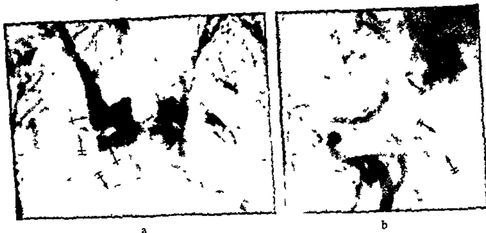
As in man, the segmental branches of the vertebro-subclavian arteries and the aorta in the rat interconnected profusely along the entire length of the vertebral column, both inside and outside the spinal canal, forming transverse and longitudinal anastomotic chains In addition, extensive anastomoses similar to those observed in man occur between the aortic segmental branches and the large arteries on the antero-lateral body-wall such as the internal mammary artery, the superior and inferior epigastric arteries

SUMMARY

The arrangement of extravertebral sources of spinal cord arteries in the rat is similar to that in man Some differences, however, do exist, concerning mainly the arrangement of spinal branches supplied by the subclavian-vertebral arteries Contrary to the situation in man, the vertebral artery in the rat appears to be the sole source of blood supply to the cervical cord A high incidence of variations or anomalies of the vertebral artery in the rat existed Vascular variations in the upper left thoracic spaces were frequent in the rat and more complicated than in man In both species, a poor supply of significant spinal cord feeders from the superior intercostal artery of the costocervical trunk was found Variations in the origin and branching of the aortic segmental arteries occur in both species In man the major variation consists of two or more intercostal arteries arising from a common stem, while the rat more often displays a rudimentary subcostal artery Finally the ileolumbar arteries in the rat are constant branches of the lumbar aorta Despite these differences in the vascular anatomy, the rat seems to be well suited for experimental comparative investigations, not feasible in man

ZUSAMMENFASSUNG

Die Anordnung der extravertebralen Versorgungen der Arterien der Wirbelsaule bei der Ratte ist der dem Menschen ahnlich Einige Unterschiede betreffen hauptsachlich den Aufbau der Spinalaste, die durch die A subclavia–A vertebralis versorgt werden Im Gegensatz zur Situation beim Menschen scheint die Vertebralarterie bei der Ratte die einzige Blutversorgungsquelle der Wirbelsaule zu sein Es besteht bei der Ratte eine hohe Frequenz von Variationen oder Anomalien der Vertebralarterie Vaskulare Variationen in den oberen linken Thoraxabschnitten waren bei der Ratte haufiger komplizierter als beim Menschen Bei beiden Spezies fand sich eine geringfugige Versorgung signifikanter Wirbelsaulen Äste von der oberen Interkostal-Arterie des costo-cervikalen Stamms Variationen im Ursprung und der Verzweigung der Aorta Segment-Arterien fand sich bei beiden Spezies



& PASSERINI 1969) Phlebography should thus not be indicated and it has also been claimed that phlebography is directly contraindicated in such cases (LOMBARDI 1972) However, in a few cases retrograde filling of the draining superior ophthalmic vein has been reported (RAMEE & SIGNARGOUT 1972, BRISMAR 1974 b)

The aim of this investigation was to establish whether a carotid-cavernous fistula can be diagnosed by orbital phlebography, and whether phlebography offers any extra information in cases with a carotid-cavernous fistula already demonstrated by bilateral carotid angiography

Material and Methods

The material consisted of 6 consecutive cases with spontaneous carotid-cavernous fistulas draining into the orbital veins, all examined with orbital phlebography as well as with bilateral carotid angiography The technique for orbital phlebography has previously been described in detail (BRISMAR 1974 a) It implicates a rapid injection of contrast medium (10 ml in 1 to 2 s) into a frontal vein while the draining facial veins are compressed

Case reports

Case 1 A 69-year-old woman with six months' history of reddening and slight pain of the right eye developed right-sided proptosis and double vision At ophthalmologic examination, in addition to exophthalmos and restricted movements of the right eye, an external venous stasis of the eye and a moderately increased ocular pressure was found

Orbital phlebography (Fig. 1 a) demonstrated normal conditions on the left side On the right side a widened superior ophthalmic vein was filled back to the cavernous sinus, that

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SPONTANEOUS CAROTID-CAVERNOUS FISTULAS

Phlebographic appearance and relation to thrombosis

GUDRUN BRISMAR and J BRISMAR

The classical symptomatology in carotid cavernous fistulas includes exophthalmos, conjunctival chemosis, lid swelling, involvement of the ocular motor nerves (particularly the sixth nerve) and a bruit localized behind the affected eye (WALSH & HOYT 1969) The clinical diagnosis offers few problems when a patient presents with all these symptoms and signs, especially if the exophthalmos is pulsating and the bruit confirmed with the stethoscope

However, in cases with carotid cavernous fistulas of spontaneous onset, some of these symptoms are often missing (TANIGUCHI et coll 1971, DJINDJIAN et coll 1973) The patient may present with only proptosis, diplopia cephalgia and a red injected eye, suggesting a possible intraorbital tumour The radiologic examination of a patient with such a tumour normally includes conventional radiography of the orbit, orbital phlebography and carotid angiography As orbital phlebography is often performed before carotid angiography, before hospitalization of the patient, some patients with a carotid cavernous fistula will be subjected to orbital phlebography on the suggestion of an intraorbital tumour

Previously, it has been reported that the intraorbital veins do not fill at orbital phlebography in cases with carotid cavernous fistulas (HAYE et coll 1970 LOMBARDI

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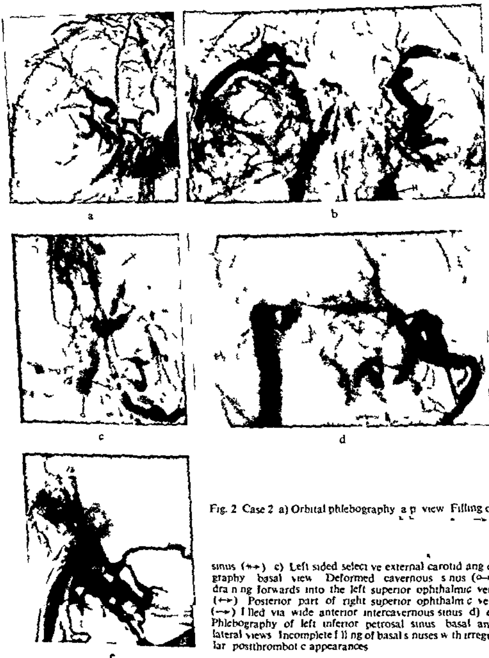


Fig. 2 Case 2 a) Orbital phlebography a p view Filling of

sinus (↠) c) Left sided select ve external carotid ang o-graphy basal view Deformed cavernous s nus (o→) dra n ng forwards into the left superior ophthalmic vein (↔) Posterior part of right superior ophthalm c vein (→) f lled via wide anterior intercavernous sinus d) e) Phlebography of left inferior petrosal sinus basal and lateral views Incomplete f ll ng of basal s nuses w th irregu lar postthrombot c appearances

had a deformed, amputated appearance Only a faint filling of the plexus of the foramen ovale on the right side was obtained and no filling of the right inferior petrosal sinus. Lateral and posterior to the cavernous sinuses, particularly on the right side some small

fistula supplied from external and internal carotid arteries on both sides Furthermore, the small atypical vessels found at phlebography proved to be identic with feeding arteries of the fistula (Fig 1 b)

Case 2 A 63-year-old, earlier healthy woman after one month's history of left sided frontotemporal headache developed a right-sided proptosis and paresis of the right oculomotor and both abducens nerves One month later she noted a pulsating bruit at the left eye in the left recumbent position Rightsided carotid angiography performed at another hospital was primarily considered normal and the patient was referred to the ophthalmologic clinic for further examinations concerning her right-sided exophthalmos

At orbital phlebography the anterior part of the left superior ophthalmic vein filled In spite of compression of the veins leading to the left orbit, on the right side filling of only the anterior two thirds of the superior ophthalmic vein was obtained (Fig 2 a) One month later the phlebography was repeated with a more forceful injection of contrast medium (Fig 2 b) In spite of filling of numerous small palpebral and periorbital veins on the right side, no filling of the superior ophthalmic vein occurred at this time On the left side a widened superior ophthalmic vein was filled back to the deformed cavernous sinus

Reviewing of the right-sided carotid angiography disclosed a carotid cavernous fistula supplied from external carotid branches and draining exclusively through the left superior ophthalmic vein

Left sided carotid angiography demonstrated that the fistula was supplied by external as well as internal carotid branches It also demonstrated the deformed appearance of the cavernous sinus and that the posterior part of the right superior ophthalmic vein was filled via a wide anterior intercavernous sinus (Fig 2 c)

Left sided phlebography of the inferior petrosal sinus confirmed the postthrombotic, irregular appearance of the basal sinuses of the skull (Fig 2 d, e)

Case 3 A 14-year-old, gravely mentally retarded girl with Down's disease and a congenital vitium after some four months' history of a reddened and injected right eye developed proptosis, decreased movements and signs of external venous stasis of the same eye No detailed ophthalmologic examination could be performed As skull films had demonstrated a soft tissue mass in the right maxillary sinus, this sinus was at first surgically exposed without any tumour being found

Orbital phlebography The first injections of contrast medium demonstrated normal conditions in the left orbit and in the left cavernous sinus and adjacent basal sinuses, while no filling of the intraorbital veins on the right side was obtained This was considered as an indication of a possible fistula, and therefore a more forceful injection of medium was made (Fig 3 a), demonstrating widening of the superior ophthalmic vein on the right side and a deformation of the right cavernous sinus No normal drainage of this sinus could be seen, but retrograde filling of an arterial branch was obtained

Selective angiography of the right internal and external carotid arteries and of the left common carotid artery (Fig 3 b, c) disclosed an arteriovenous fistula exclusively supplied from the accessory meningeal branch of the right maxillary artery and draining only into the right superior ophthalmic vein

Case 4 A 48-year-old man with a history of operated and healed pulmonary tuberculosis after a common cold developed increasing pains and reddening of the right eye and a slight proptosis The patient was hospitalized on the suggestion of an intraorbital phlegmon or a

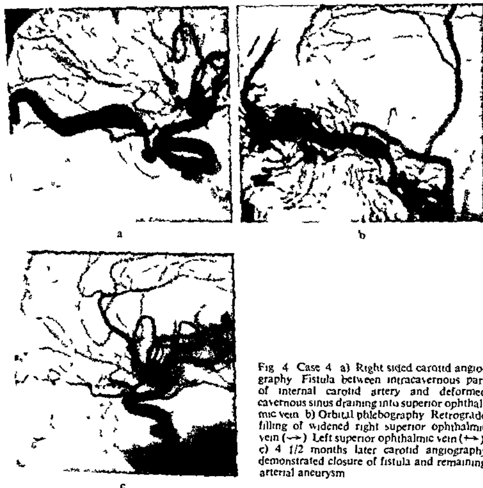


Fig 4 Case 4 a) Right sided carotid angiography Fistula between intracavernous part of internal carotid artery and deformed cavernous sinus draining into superior ophthalmic vein b) Orbital phlebography Retrograde filling of widened right superior ophthalmic vein (→) Left superior ophthalmic vein (↔) c) 4 1/2 months later carotid angiography demonstrated closure of fistula and remaining arterial aneurysm

Case 5 A 61 year-old woman 2 weeks after operation for a glaucoma of the left eye (*operation* confined to anterior segment of the bulb) developed reddening proptosis abducens nerve palsy decreased vision pains and periorbital oedema of the right eye

Orbital phlebography at the local hospital (Fig 5 a) performed on the suggestion of an intraorbital expansivity revealed normal findings on the right side while on the left side no *filling of intraorbital* veins was achieved As in addition in spite of a left sided injection of medium the filling of the veins adjacent to the left orbit was deficient an arteriovenous fistula was suggested

This was confirmed by a left-sided carotid angiography (Fig 5 b) demonstrating a fistula supplied from the internal carotid artery and drained through the left superior ophthalmic vein

Two months after the first examination a new orbital phlebography with a more forceful injection of *medium* (Fig 5 c) demonstrated an occlusion of the left superior ophthalmic vein as proven by a distinct stop of contrast medium and filling of several small palpebral veins

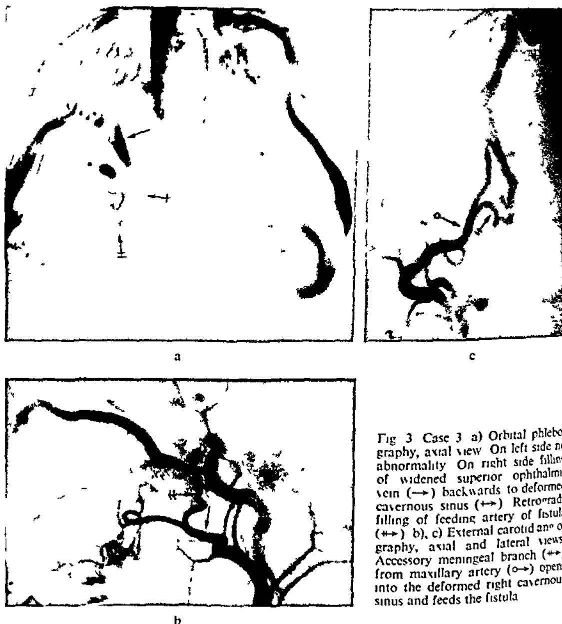


Fig 3 Case 3 a) Orbital phlebography, axial view On left side no abnormality On right side filling of widened superior ophthalmic vein (—→) backwards to deformed cavernous sinus (↔) Retrograde filling of feeding artery of fistula (⇸) b), c) External carotid angiography, axial and lateral views Accessory meningeal branch (⇸) from maxillary artery (o→) opens into the deformed right cavernous sinus and feeds the fistula

tumour, when suddenly symptoms from the right eye increased more marked proptosis, total ptosis and ophthalmoplegia developed, vision decreased and a bruit could be heard

Right sided common carotid angiography (Fig 4 a) demonstrated a fistula supplied from the intracavernous portion of the right internal carotid artery, probably via a ruptured arterial aneurysm, and draining into the right superior ophthalmic vein

Orbital phlebography (Fig 4 b) with forceful injection permitted retrograde filling of the widened right superior ophthalmic vein back to the deformed right cavernous sinus

Left-sided carotid angiography was normal An occlusion of the fistula was tried two months later using a Fogarty balloon placed in the internal carotid artery—the balloon had, however, to be withdrawn immediately as the patient developed ischemic signs as the balloon was inflated The clinical symptoms and signs then successively decreased and an angiography another three months later (Fig 4 c) demonstrated closure of the fistula

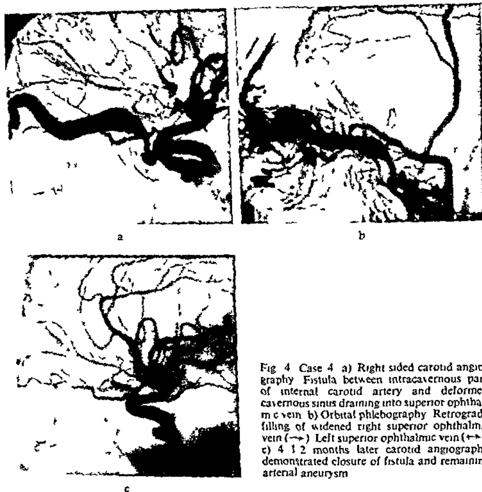


Fig 4 Case 4 a) Right sided carotid angiography Fistula between intracavernous part of internal carotid artery and deformed cavernous sinus draining into superior ophthalmic vein b) Orbital phlebography Retrograde filling of widened right superior ophthalmic vein (→) Left superior ophthalmic vein (⇸) c) 4 1 2 months later carotid angiography demonstrated closure of fistula and remaining arterial aneurysm

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Two months after the first examination a new orbital phlebography with a more forceful injection of medium (Fig 5 c) demonstrated an occlusion of the left superior ophthalmic vein as proven by a distinct stop of contrast medium and filling of several small palpebral veins

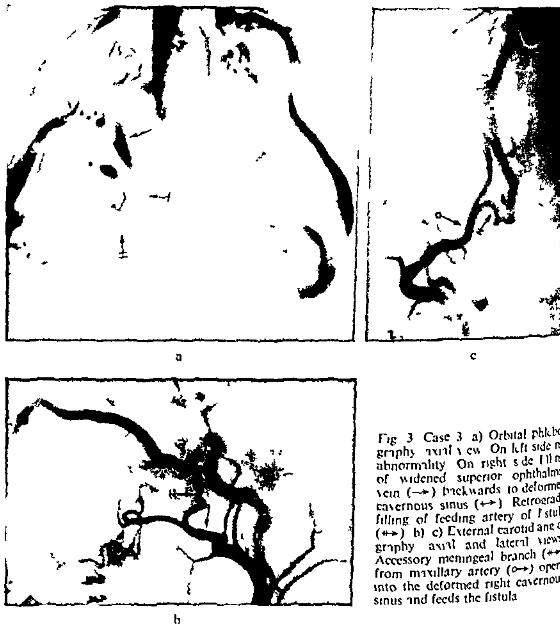


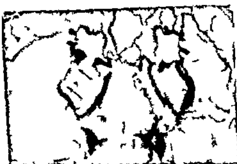
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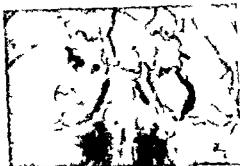
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a


b


c


d


e

right super or ophthalm c ve n already empty thus nd cat ng a f stula c) Orb tal phlebography ax al v ew conf rms f ll ng defect in right superior ophthalm c ve n (—►) In add on r ght cavernous s nus has an amputated appearance (+→) d) Phlebography of right nferior petrosal s nus Irregular post thrombot c appearance of nfer or petrosal s nus (+→) and cavernous s nus on r ght s de (+→) e) Lateral view of same exam nat on demonstrates retrograde f ll ng of branches of external ca ot d artery (∘+→) and f ll ng of carot d s phon (+→) and internal carot d branches (o→)

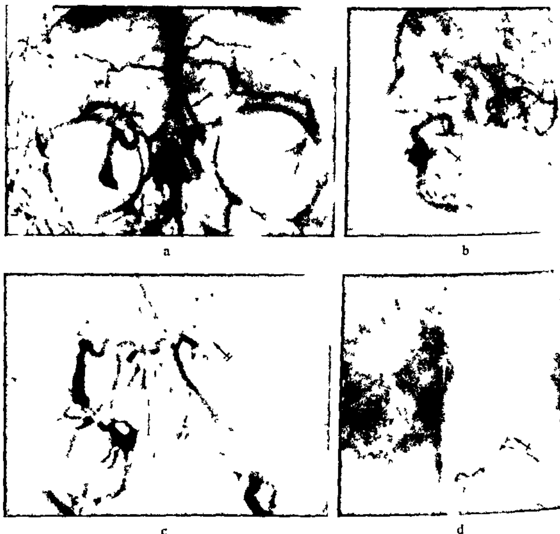


Fig 5 Case 5 a) Orbital phlebography, a p view In spite of injection of medium on left side (→) deficient filling of periorbital veins on left side No filling of left superior ophthalmic vein b) Left sided carotid angiography confirmed arteriovenous fistula draining through superior ophthalmic vein on left side (↔) c) Orbital phlebography (a p view) two months later Occlusion of left superior ophthalmic vein and filling of several small palpebral veins on left side (↔) d) Occlusion of superior ophthalmic vein (↔) confirmed by right sided carotid angiography

A right-sided carotid angiography confirmed this occlusion (Fig 5 d) The clinical symptoms had at this time decreased

Case 6 A 75-year-old woman had since 15 months noticed reddening of the right eye and a 'bubbling' sensation from the right ear when a right sided exophthalmos rapidly developed At the same time the bubbling sensation changed to a pulse synchronous bruit Raised intraocular pressure and external venous injection was found in the right eye, while the vision was normal

Orbital phlebography (Fig 6 a) demonstrated a filling defect in the lumen of the right superior ophthalmic vein In spite of this, and in spite of the injection of medium being right-sided a rapid washing away of the medium from the right superior ophthalmic vein as compared to the left, was observed (Fig 6 b), indicating a fistula Furthermore the right cavernous sinus had an abnormal appearance (Fig 6 c)

ous sinus was demonstrated by phlebography of the inferior petrosal sinus (HANAFEE 1965) in cases 2 (Fig 2 d, e) and 6 (Fig 6 d, e) In case 6 a thrombus partially occluding the lumen of the superior ophthalmic vein on the side of the fistula was demonstrated at phlebography, in cases 2 and 5 a total occlusion of the same vein developed or propagated between two angiographic examinations (Figs 2 a, b, 5 b, c) In case 4 (different from the other cases as the fistula was fed exclusively by one internal carotid artery and probably caused by a ruptured arterial aneurysm) the fistula closed (Fig 4) between two examinations

That carotid-cavernous fistulas can heal spontaneously through thrombosis has long been known LOCKE (1924) reported on 4 instances of spontaneous cure in 27 cases observed while SATTLER (1920) described spontaneous cure in 16 of 322 cases collected from the literature In one case observed by KNUDTZON (1950) and in two cases by LO CASCIO (1960) cure was accompanied by extensive aseptic thrombosis of the cavernous sinus or orbital veins The technique of selective angiography, by giving an improved concentration of medium in the fistula, permits a detailed demonstration not only of the arterial supply of the fistula but also of its drainage. TANIGUCHI et coll (1971) presented 11 cases of carotid-cavernous fistulas with spontaneous onset (one of them supplied exclusively by one external carotid artery) and suggested that at least some of them were partly thrombosed with only one or two outlets remaining In two of their cases the fistula closed during angiography It is an open question whether the closure of the fistula in case 4 and the thrombosis of the superior ophthalmic veins in cases 2 and 5 in the present material were provoked by the angiographic procedure

External carotid artery supply to a spontaneous carotid-cavernous fistula was previously considered rare (WALSH & HOYT 1969) but recently several cases with fistulas supplied partly or exclusively by the external carotid arteries have been presented (NEWTON & HOYT 1970, DJINDJIAN et coll 1973) Cases 1, 2, 3, 5 and 6 in the present material belong to the same category Of these, case 3 is unique by having only external carotid supply—one accessory meningeal artery—the other four cases had an internal carotid supply as well

The etiology of spontaneous carotid-cavernous fistulas is obscure The condition is most frequent among middle aged women (WALSH & HOYT) Spontaneous rupture of carotid arterioles, rupture of small intracavernous congenital carotid aneurysms, arteriosclerosis and disorders of elastic tissue have been suggested as possible etiologies for fistulas between the internal carotid artery and the cavernous sinus (WALSH & HOYT), while dural arteriovenous malformations have been suggested as a cause of external carotid-cavernous fistulas (NEWTON & HOYT 1968)

No theory explaining the high frequency of thrombosis in association with carotid-cavernous fistulas has been presented in the literature The thrombosis might be a consequence of the irritating effect of the high intravenous pressure and the increased blood flow on the venous wall or the thrombosis and fistula could be different aspects of a localized vascular disorder A third possible explanation is that the altera-

A right-sided carotid angiography disclosed a carotid-cavernous fistula supplied by external as well as internal carotid artery branches and drained exclusively into the right superior ophthalmic vein

Right-sided retrograde phlebography of the inferior petrosal sinus confirmed the irregular appearance of the right cavernous sinus and demonstrated similar changes in the right inferior petrosal sinus (Fig 6 d) In association with the last injection at the sinus examination the patient described transient intense pains—at this injection filling through the fistula of its internal as well as external carotid supply was achieved (Fig 6 e) Following this examination the exophthalmos and the periorbital oedema of the patient transitorily increased, while the vision transitorily decreased

Discussion

The technique of orbital phlebography used implicates a more rapid injection of contrast medium than previously used by other authors In combination with a complete compression of the draining facial veins it permits a countercurrent filling of not only the ophthalmic veins draining a carotid-cavernous fistula but also of the affected part of the cavernous sinus, as is evident from the case reports In three cases (cases 1, 3 and 6) the medium at phlebography could even be forced out into feeding arteries (Figs 1 a, 3 a, 6 e) Provided the injection is intravasal and the compression of facial veins effective, non-filling of the intraorbital veins is always pathologic if there exist well developed communicating veins between the injection site and the orbit Non-filling may be caused by a large intraorbital tumour compressing the veins or by extensive intraorbital venous thrombosis If this is the case, however, a distinct stop of the contrast medium column in the superior ophthalmic vein or in its tributaries is normally demonstrated Furthermore, with a good technique, filling of palpebral veins is achieved (Figs 2 b, 5 c) When incomplete filling of the orbital veins is caused by a fistula, there is no distinct posterior limit of the contrast medium column in the veins and the medium (if any has entered the orbit) is rapidly washed away (Fig 6 a, b) Medium is furthermore washed away not only from the intraorbital veins but also from the facial veins in the vicinity of the orbit (Fig 5 a) When a fistula is suggested, a still more rapid injection of medium in association with an effective compression of all draining facial veins will often permit countercurrent filling of the orbital veins draining the fistula

When a fistula exists between arterial branches and the cavernous sinus it would be expected that all veins connected to the cavernous sinus take part in its drainage However, in all 6 cases presented in this report, the fistula drained exclusively into the veins of one orbit That this is not only an effect of flow mechanics is proven by the fact that though medium at phlebography was forced over into the feeding arteries in 3 cases (cases 1, 3 and 6) no filling of additional draining veins was achieved In addition, in all 6 cases, the cavernous sinus had a deformed, amputated appearance These findings could only be explained by extensive thrombosis of the cavernous sinus and its draining veins Thrombosis of the veins in the vicinity of the cavern-

with signs of thrombosis Phlebography permitted a diagnosis of a fistula in all 6 cases

Phlebography gives additional information concerning thrombosis of the intra-orbital veins and the venous sinuses of the skull base as compared to carotid angiography (bilateral selective internal and external carotid injections) and thus forms a valuable complement to these examinations

No explanation can yet be offered to the high incidence of thrombosis in association with carotid cavernous fistulas The tendency towards spontaneous cure through thrombosis motivates restrictivity with mutilating operations on the internal carotid arteries, while catheter embolisation of external carotid branches to the fistula seems motivated in order to reduce the flow through the fistula

SUMMARY

Six consecutive cases with spontaneous carotid-cavernous fistulas were examined with orbital phlebography and bilateral carotid angiography One of the fistulas was fed only by one internal carotid artery, 1 only by the accessory meningeal branch of the maxillary artery, while 4 were supplied by external as well as internal carotid arteries The findings at phlebography seem to be characteristic Thrombosis was demonstrated in all 6 cases Different mechanisms for the genesis of thrombosis in association with carotid-cavernous fistulas are proposed Alternative therapy methods are discussed

ZUSAMMENFASSUNG

Sechs aufeinanderfolgende Falle mit spontanen Sinus cavernosus-Fisteln wurden mit orbitaler Phlebographie und bilateraler Carotisangiographie untersucht Eine der Fisteln wurde nur durch eine Arteria carotis interna, eine nur durch den accessorischen meningealen Ast der Arteria maxillaris versorgt [illegible]
wie interna versorgt wurden [illegible]
zu sein Thrombosen wurden [illegible]
nismen fur das Auftreten der [illegible]mbose verbunden mit Sinus cavernosus Fisteln werden vermutet Alternative therapeutische Methoden werden diskutiert

RÉSUMÉ

Six cas consécutifs de fistule carotido-caverneuse spontanee ont ete examinés par phlébographie orbitaire et par angiographie carotidienne bilaterale Une des fistules était alimentée seulement par une carotide interne, une seulement par la branche méningee accessoire de l artère maxillaire interne alors que [illegible]
et interne Les résultats de la phléb[illegible]
mis en évidence une thrombose dan[illegible]
l apparition de la thrombose asso[illegible] [illegible] discutent les autres méthodes de traitement

tions in flow mechanics caused by a fistula may lead to a reduction, stagnation or even reversal of flow in some of the normal drainage routes of the cavernous sinus (cf the principle of the water aspirator) and thus provoke thrombosis

While fistulas with an exclusive or predominant external carotid supply are well suited for distal ligation of the feeding external carotid branches, or preferably (as the occlusions of the arteries are more peripheral) percutaneous transcatheter embolisation of these branches, fistulas with a significant internal carotid supply offer considerable therapeutic problems In order to permanently cure a fistula all its arterial supply has to be eliminated An extensive operation in order to eliminate the internal carotid supply of fistulas has been developed by HAMBY (1964) It includes intracranial carotid and ophthalmic artery clipping immediately followed by muscle embolisation of the internal carotid artery and ligation and section of the common internal and external carotid arteries However, when there is a bilateral internal carotid supply to the fistula this method will not be possible to use The marked tendency towards spontaneous cure by thrombosis is a strong argument to postpone extensive operations as long as possible (cf case 4) The documented association between the minor disturbances in circulatory dynamics or blood chemistry caused by carotid angiography and a spontaneous closure of a fistula (NEWTON & HOYT, TANIGUCHI et coll) suggests the possibility of alternative treatments As these fistulas, though often having multiple arterial feeders, not seldom drain into only one vein, it might be possible to try to initiate thrombosis of this vein by attacking the venous side Operations confined to tying off the ophthalmic veins draining the fistula have previously been successfully used (WALSH & HOYT) Perhaps only a temporary change in the flow mechanics of the vein, eventually in combination with an injection of some irritating medium into the vein, is required in order to provoke a thrombosis in some cases It might in fact even be possible that the phlebographic examination itself contributed to the cure of the patients 4 and 5 in the present material

Conclusions

The case histories in these 6 patients confirm the difficulty in arriving at a correct clinical diagnosis of carotid cavernous fistulas without the aid of neuroradiologic procedures The patients are often referred to a phlebographic examination on the suggestion of an intraorbital tumour It is thus important to recognize the phlebographic signs produced by a fistula

The presence of a fistula is suggested if the intraorbital veins on one side, in spite of an optimum injection technique, are not filled A defect filling of also the periorbital veins speaks in favour of a fistula A more forceful injection of medium in combination with an effective compression of facial veins often permits a counter current filling of the draining veins of the fistula These veins are wider than normally and the medium is rapidly washed out again A countercurrent filling may be achieved even of the affected cavernous sinus, which in all 6 cases had a deformed appearance

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RADIOLOGY FOR DETECTING BRAIN TUMOR RECURRENCES

G SCHWARZ, H SCHREYER and G ARGYROPOULOS

Following the resection of a brain tumor certain abnormalities such as gliosis, hydrocephalus or vascular insufficiency may cause clinical symptoms and signs, which mimic those of tumor recurrence No distinction can be made by echo- or electroencephalography On the other hand cerebral angiography and pneumography will demonstrate the differences in detail (FIEBACH et coll 1972, FRIEDEMANN et coll 1962) but hospitalisation of the patient is required Neither of these methods is suitable for routine follow up, but should only be used when distinct symptoms or signs of a recurrence are present If recurrences of benign tumors, which can easily be removed successfully, are detected late irreparable damage may be [illegible]

For [illegible]
little s [illegible]
high a [illegible] detecting tumor recurrences Brain scanning using ^{99}Tc^{m}-pertechnetate is such a method (KUBA et coll 1972, KVICALA & BOUCEK 1962, WILKINS et coll 1967) In the following report, postoperative brain scans are compared with the results of angiography and encephalography on the one hand, and the findings at operation and autopsy on the other The efficacy of radiologic and nuclear methods in the early detection of recurrent brain tumors is compared

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Table 1

Frequency of positive (+) negative (−) and not performed (0) examinations related to location

	No of cases	Scintigraphy			Angiography			Encephalography		
		+	−	0	+	−	0	+	−	0
Recurrent tumors of the hemispheres	37	29	2	6	34	1	2	11	2	24
Recurrent tumors near the base	8	5	2	1	3	0	5	8	0	0
Total	45	34	4	7	37	1	7	19	2	24

demonstrated an enlarged left ventricle, and displacement of the whole ventricular system to the left, which was attributed to a postoperative atrophy of the brain At angiography, however, a vascular recurrence in the left hemisphere was detected (Fig 2) In the third case increased isotope uptake was found in the gliotic wall of a benign cyst This observation was made 3 months after the excision of an astrocytoma in the left temporo occipital region Both angiography and encephalography were considered normal

In the second group with tumor recurrences near the base, scintigraphy produced two false negative results In the first case there was a walnut size recurrence 4 years after resection of a spongioblastoma of the optic nerve At scintigraphy the activity within the tumor could not be distinguished from the normal activity of the base of the skull On the other hand, at encephalography a narrowing of the cisterns above the optic chiasma and an elevated third ventricle were evident The scan was also negative in the second case in which there was a recurrence 6 years after the removal of a craniopharyngeoma although evident abnormalities were found at both angiography and encephalography (Fig 3) The detailed results appear in Table 2

Discussion

Brain scintigraphy after craniotomy demonstrates an accumulation of activity in the outer zone of the bone flap regardless whether it is osteoclastic or osteoplastic (Gradduck & Duggan 1969, Oldendorf & Isaka 1969) This increased activity disappears after a period of 6 months to 3 years (Hurley 1972) Within the operative region of the brain a diffusely increased activity exists for up to 3 weeks (van Vliet et coll 1965) Difficulties in distinguishing between the uptake caused by postoperative changes and that caused by recurrences arise only in the case of superficial tumors which, for the most part, are meningeomas

The differential diagnosis is mainly based on repeated follow-up examinations Increasing activity indicates a recurrent tumor For this reason it is important to take into account any pre-existing activity in the region of craniotomy Moreover, it is advantageous to compare the type and position of the lesion with a preoperative

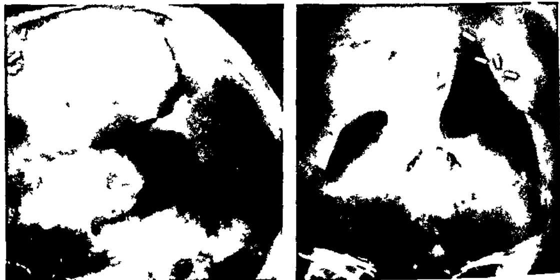


Fig 1 58 year-old female 3 years after removal of astrocytoma in the left parietal region Encephalography Dilated left ventricle displacement of left lateral ventricle to left Postoperative atrophy was considered to be the cause of displacement

Material and Methods

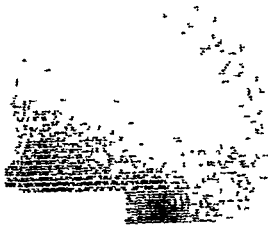
In 45 patients with signs of brain tumor recurring after operation 77 brain scans were performed using 10 mCi $^{99}Tc^{m}$ pertechnetate intravenously Scans were made in four projections the first 30 min after the injection the last two hours thereafter A total of 74 angiographies of the carotid arteries were performed using 10 ml Urografin 60 % exposing 5 films with a frequency of 2/s and 5 films with 1/s In 25 cases encephalography and in 3 cases gas ventriculography, following direct puncture of a lateral ventricle, were performed Routinely, brain scans were repeated every 3 to 6 months after operation Angiography and encephalography were used when scans were suggestive of recurrences or when clinical symptoms and signs were present

Results

A distinction was made between recurrent tumor growth in the cerebral hemi spheres and growth near the base The results of all three diagnostic methods in each group appear in Table 1 The focus of interest lies in the false negative and false positive findings Discrepancies existed in 3 cases with peripherally located recurrent tumors of the hemisphere In one scintigraphy was negative despite a cystic recur rence 8 months after the removal of a glioblastoma in the parieto occipital region and postoperative irradiation The angiography in this case demonstrated an oval area without blood vessels which was diagnosed correctly to be a cyst In the second case, scintigraphy and encephalography were considered negative in a recurrence 3 years after operative removal of an astrocytoma in the left fronto parietal region No pathologic accumulation of activity existed while the encephalography (Fig 1)



a

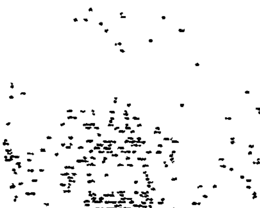


b

F g 3 5 yea -old boy one year after removal of a cran opharyngeoma a) Encephalography Elevat on of th rd ventr cl b) suprasellar mass (→) b) Sc nt graphy No abnormality



a



b

F g 4 38 year-old male 2 years after removal of frontal astrocytoma a) R ght carot d ang ography Poo ly vascular zed mass n the r ght frontal reg on no d splacement of pericallosal artery b) Sc nt graphy La ge symmetr c frontal recurrence

have reached a certa n size because minor displacements of vessels may also be caused by operat on itself as well as by postoperative cerebral atrophy and scarring In many cases arteries are occluded by clips during operation implying that a direct comparison with preoperat ve angiography is of l mited value Tumor growth beyond the med an sag ttal plane or mult locular recurrences can only be demonstrated by ang ography of the contralateral hemisphere (Fig 4) In the diagnosis of recurrences of basal brain tumors encephalography produces the best results and cannot be replaced by bra n scanning since a d fferentiat on between the uptake in brain tumors



Fig 2 Same case as in Fig 1 Left carotid angiography (arteries white veins black) Poorly vascularized recurrence in the left parietal region (→)

Table 2

Frequency of positive ( ) negative ( ) and not performed (0) examinations related to microscopy

Microscopy	No of cases	Scintigraphy			Angiography			Encephalography		
		+		0	+	−	0	+	−	0
Astrocytoma	19	14	2	3	18	1	0	5	1	13
Glioblastoma	8	5	1	2	6	0	2	2	0	6
Meningeoma	8	7	0	1	8	0	0	3	0	5
Metastasis	3	3	0	0	3	0	0	1	0	2
Craniopharyngeoma	2	1	1	0	1	0	1	2	0	0
Ectopic pinealoma	2	1	0	1	1	0	1	2	0	0
Acoustic neurinoma	1	1	0	0	0	0	1	1	0	0
Gliosis	1	1	0	0	0	1	0	0	1	0
Thalamic tumor	1	1	0	0	0	0	1	1	0	0
Total	45	34	4	7	37	2	6	17	2	26

scintigraphy Any increased activity in the depths of the cerebral hemisphere, which is apparent 3 months after operation, must be attributed to a recurrence In contrast to surface lesions, deep lesions can only be demonstrated by scintigraphy in four different projections

The vascularity of a recurrence usually corresponds to the vascular appearance of the primary tumor Thus recurrences of well vascularized tumors are easily demonstrated by angiography which also gives a clear picture of their location On the other hand, poorly vascularised recurrent tumors can only be detected when they

Die Enzephalographie ist die bevorzugte Untersuchung, um ein Rezidiv in der Nähe der Schadelbasis festzustellen Die Angiographie ist die beste Methode, um ein Rezidiv in der Nahe der Oberflache im Gebiet der Kraniotomie nachzuweisen und ist unumganglich vor einer wiederholten Operation

RESUMÉ

Les auteurs comparent l'efficacite de l angiographie, de la scintigraphie au $^{99}Tc^{m}$-pertechnetate et de l encéphalographie pour la detection de récidive tumorale chez 45 malades après résection de tumeur cérebrale Aucune methode n'est toujours préferable et la meilleure façon de detecter une recidive tumorale particulière est basee sur la localisation et la nature de la tumeur primitive La scintigraphie est la méthode de choix pour faire une surveillance post-operatoire de routine Pour les tumeurs des hemisphères cerébraux, on peut remplacer l angiographie par la scintigraphie cérebrale qui est une méthode moins penible pour le malade et ne néce...

... le est essentielle avant une reintervention

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KV...

OLI ... and ISAKA Y Interference of scalp and skull with external meas... of brain ...

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in this location and the activity of the base of the skull is frequently impossible because of insufficient resolution.

Conclusion

To diagnose recurrences it is not possible to rely on one investigation alone. The best way to diagnose the recurrent tumor must be chosen with regard to the type and location of the primary tumor. The results indicate that angiography can be replaced by scintigraphy for cerebral hemisphere tumor recurrences with less risk to the patient but without loss of diagnostic accuracy. The diagnosis is facilitated by a comparison with a preoperative scintigraphy. For this reason a preoperative scan should be performed in every patient even if the diagnosis has already been established by other methods. There is unlikely to be any objection raised by the patient against a scintigraphy even if he is symptom free. Furthermore, repeated follow up examinations are possible which permit the early detection and operation of rapidly growing recurrences, thus preserving as much brain tissue as possible. Encephalography is the method of choice for recurrences of basal brain tumors. In all cases presented here this method was successful. Angiography should be performed in cases where a scan suggests a recurrence in the region of the craniotomy and no clear proof is otherwise possible. Angiography is essential as a preoperative examination to demonstrate the vascularity of the original operative region, information which is of value before reoperation.

SUMMARY

Angiography, $^{99}Tc^{m}$-pertechnetate scintigraphy and encephalography are compared in their efficacy in the detection of tumor recurrences in 45 patients following brain tumor resection. No single method is always preferable and the best way of detecting a particular tumor recurrence is based on the location and nature of the primary tumor. Scintigraphy is the method of choice for performing routine postoperative follow-up. In cerebral hemisphere tumors angiography may be replaced by brain scanning which is a lesser procedure for the patient and does not necessitate hospitalisation. Encephalography is the examination favoured for detecting recurrences near the base of the skull. Angiography is the best method for demonstrating recurrences near the surface in the region of craniotomy and is essential before reoperation.

ZUSAMMENFASSUNG

Angiographie, $^{99}Tc^{m}$ Pertechnetatszintigraphie und Enzephalographie wurden in ihrer Effektivitat verglichen. Rezidive von Tumoren bei 45 Patienten im Anschluss an die Resektion eines Gehirntumors festzustellen. Keine einzelne Methode ist immer vorzuziehen und die beste Art, das Rezidiv eines gewissen Tumors festzustellen beruht auf der Lokalisation und der Natur des primaren Tumors. Die Szintigraphie ist die Methode der Wahl um routinemassige postoperative Nachuntersuchungen vorzunehmen. Bei Tumoren der Grosshirnhemisphere kann die Angiographie durch die Gehirnszintigraphie ersetzt werden, welche fur den Patienten ein geringerer Eingriff ist und keine Aufnahme im Krankenhaus verlangt.

Die Enzephalographie ist die bevorzugte Untersuchung, um ein Rezidiv in der Nähe der Schädelbasis festzustellen Die Angiographie ist die beste Methode, um ein Rezidiv in der Nahe der Oberfläche im Gebiet der Kraniotomie nachzuweisen und ist unumgänglich vor einer wiederholten Operation

RÉSUMÉ

façon de detecter une récidive tumorale particuliere est basée sur la localisation et la nature de la tumeur primitive La scintigraphie est la methode de choix pour faire une surveillance post-operatoire de routine Pour les tumeurs des hémispheres cerebraux, on peut remplacer l angiographie par la scintigraphie cerebrale qui est une methode moins penible pour le malade et ne nécessite pas une hospitalisation L'encéphalographie est l'examen a préferer pour detecter des recidives près de la base du crâne L'angiographie est la meilleure methode pour mettre en évidence des récidives pres de la surface dans la region de la craniotomie et elle est essentielle avant une reintervention

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MAGNIFICATION ANGIOGRAPHY IN THE EVALUATION OF TRANSPLANTED KIDNEYS

LEENA LAASONEN, JOHAN EDGREN and TOR MATTSSON

In the early postoperative period after kidney transplantation ischaemic tubular necrosis and immunologic rejection are the main causes of insufficient graft function, vascular and ureteric complications are less frequent Later, impairment of graft function is usually due to rejection or to stenosis of the arterial anastomosis Angiography is useful in the differential diagnosis of these conditions (KAUDE et coll 1970, VOEGELI et coll 1974), but the differentiation between tubular necrosis and acute rejection is sometimes difficult (NAVANI et coll 1971)

Direct serial magnification angiography has recently developed into a useful clinical tool (BOOKSTEIN & POWELL 1972, RAO & SOONG 1973) It has been used in the evaluation of parenchymatous renal lesions in hypertensive patients (COPE et coll 1974), and in other renal diseases as well (MENA et coll 1973) Magnification angiography was found particularly helpful in the diagnosis of polyarteritis nodosa (SIDAWAY 1972) and in cases of unexplained haematuria (STEIN 1973)

To the best of our knowledge no reports are available on the use of the magnification technique on transplanted kidneys As the primary site of rejection is the vascular endothelium (WILLIAMS et coll 1973) this technique should improve the assessment of the condition of renal transplants

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The article is based on a report made at the Thirty third Congress of the Scandinavian Radiological Society, June 1974, Uppsala, Sweden Submitted for publication 14 April 1975

Table

Angiographic and clinical diagnosis in 34 examinations of renal allografts

Angiographic diagnosis	No of cases	Vascular irregularities		Occlusions		Interlobular arteries not filled	Oedema	Circulation time >2 s	Clinical diagnosis	No of cases
		I	A	I	A					
Acute rejection	17	9	17	3	16	10	15	14	Acute rejection	13
									Tubular necrosis	4
Chronic rejection	7	7	7	3	7	1	0	1	Chronic rej	5
									Acute rej	2
Tubular necrosis	3	1	2	0	2	1	1	0	Tubular necrosis	3
Condition after rejection	2	0	2	1	2	1	0	0	Condition after rejection	2
Stenosis of the anastomosis	5	0	3	0	1	1	0	2	Stenosis of the anastomosis	5

I interlobal arteries
A arcuate arteries

Material and Methods

The material consisted of 34 consecutive examinations of 31 patients with kidney transplantation, 20 men and 11 women, aged 16 to 60 years Four patients received their kidney grafts from living relatives and 27 of the grafts were necropsy kidneys. The time interval between transplantation and angiography ranged from 2 days to 4 years and 8 months, and 14 examinations were performed within 10 days after transplantation

The indication for angiography was possible rejection in 17 patients, delayed onset of renal function after the transplantation in 11, and in 5 hypertension with a bruit over the graft suggesting stenosis of the anastomosis In one patient the indication was probable bleeding from the operative area

Percutaneous catheterization of the ipsilateral femoral artery was performed and the tip of the catheter was placed at the origin of the internal iliac artery Isopaque 60 % (350 ml I/mg). 15 to 20 ml, was injected at a pressure of 1 5 to 2 0 kg/cm²

Conventional angiography was performed using a heavy anode tube with a 1 2 mm focal spot Exposure data 640 mA, 0 08 to 0 1 s, 80 to 90 kV For magnification angiography a tube with a 0 3 mm nominal focal spot was used, and 100 to 120 mA,



Fig 1 Female, aged 26 years, 53 days postoperatively Clinically and angiographically early stage of chronic rejection a) Conventional angiography Interlobular arteries barely visible b) Magnification angiography Interlobular arteries clearly demonstrated glomeruli visible In the lower pole, occluded interlobar artery with large infarction

0 16 s, 85 to 90 kV The tube was placed 45 cm above the table top, which meant an FFD of 90 cm, giving a magnification of approximately ×2 The exposures were made without a grid, conventional film and high speed intensifying screens were used (Siemens Special, super high speed)

In 17 cases a preliminary film was exposed with a test plate on the patient s abdomen The resolution was determined visually and was 1 52±0 27 line pairs/mm in the conventional films and 2 36±0 42 in the magnification films

The following details were recorded in both the conventional and the magnification films Visibility of the distal arterial branches, occurrence and site of arterial occlusions, irregularities of the arteries, and the presence of oedema, *i e* enlargement of the kidney and stretching of the vessels The arterial circulation time determined from the conventional angiography was defined as the time interval between the last portion of contrast medium in the renal artery and the emptying of the cortical arteries A circulation time exceeding 2 seconds was regarded as prolonged The inter



(For legend see opposite page)

lobular arteries were recorded as either visible or not visible because their small calibre did not permit more detailed assessment of their structure

The diagnosis of acute rejection was based on the presence of oedema prolonged arterial circulation time and poor filling of the cortical arteries and of chronic rejection on general narrowing of the arteries with irregularities and occlusions Tubular necrosis was suggested when none of these abnormalities were present in patients with non functioning grafts in the early postoperative period

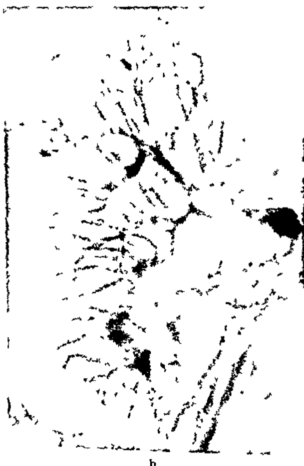


Fig 2 Female aged 16 years 9 days postoperatively Early stage of irreversible acute rejection confirmed by percutaneous biopsy a) Conventional angiography b) Magnification angiography Irregular arteries well demonstrated by magnification

Results

The patients were grouped according to the radiologic diagnosis (Table) The final clinical diagnosis was made from the clinical course and fine needle aspiration biopsy (PASTERNACK 1968) in 25 cases percutaneous biopsy in 5 cases operative biopsy in 3 cases and autopsy in 1 case In 13 of the 17 patients examined because of clinically suggested acute rejection the diagnosis was correct but the other 4 patients had tubular necrosis Of the 7 patients in whom chronic rejection was suggested 2 had acute rejection The intrarenal condition of the 5 patients with stenosis of the anastomosis was considered to be within normal limits 1 patient in addition had chronic rejection

A survey of the 26 cases with technically adequate magnification films showed that 19 of these afforded more information than the conventional angiographic films Magnification angiography demonstrated interlobular arteries in 18 cases and glomeruli in 3 of these (Fig 1) On the corresponding conventional films interlobular arteries were visible in 15 cases In 2 patients irregularities of small vessels were detected only on the magnification films In the remaining 14 cases the advantage of the magnification angiography was better definition of the peripheral arteries and easier detection of vascular abnormalities (Fig 2)



b

(For legend see opposite page.)

In 7 cases the magnification angiography did not provide any additional information although technically satisfactory In 4 of these patients even the conventional angiography revealed a normal vascular anatomy with good filling of the interlobular arteries In the remaining 3 patients the interlobular and arcuate arteries were already severely involved and thus the magnification could not possibly afford any additional information

In 8 cases there was loss of detail mainly due to technical inadequacy of the films The site of the transplanted kidney in the iliac fossa places heavier demands on the technique than the normally positioned kidneys Optimum focal spot geometry is achieved at 100 kV with tube currents of under 100 mA (MATTSSON 1968) This relatively high kV causes loss of contrast and the rather low loading capacity limits the choice of exposure values To minimize the effect of these factors the magnification

angiography was performed in supine position This is not always the ideal projection for the kidney, and may account for loss of details

Discussion

The basic mechanism of allograft rejection is not yet fully understood The arterial side of the vascularity plays the key role in the process, and cortical ischaemia is an important element in the genesis of tissue destruction (HOLLENBERG et coll 1968a) Microscopically, acute rejection is characterized by perivascular and interstitial infiltration of mononuclear cells and fibrinoid necrosis of small vessels (DEODHAR & BENJAMIN 1971) The angiographic abnormalities include oedema, a prolonged arterial circulation time, and poor filling of the cortical vessels The nephrographic effect is poor, and the borderline between cortex and medulla is hard to define These changes are all secondary, and suggest that in the early stages of rejection the lesions take place in vessels smaller than those visible at angiography even when the magnification technique is used Slight vascular irregularities were common in the present material As they occurred both in patients with an active rejection and as residua of healed rejections, as well as in grafts with tubular necrosis, their diagnostic value was considered small

Tubular necrosis is common after transplantation of necropsy kidneys Its major cause is thought to be vasoconstriction during the agonal period of the donor (BELZER et coll 1970) Renal cortical ischaemia has been stated to be present in patients with tubular necrosis (HOLLENBERG et coll) The latter authors found similar angiographic abnormalities as in acute rejection KAUDE et coll set angiographic criteria for the differentiation of acute rejection and tubular necrosis while POKIESER (1971) found no abnormalities specific to tubular necrosis In the present material 4 patients with tubular necrosis were considered to have typical changes indicating acute rejection These findings are in agreement with those of NAVANI et coll , that a differentiation of rejection from tubular necrosis is difficult or impossible

Microscopically, chronic rejection is characterized by a severe involvement of the small and medium sized arteries, with marked subintimal fibroplasia and narrowing of the lumen The irregularities of the large intrarenal vessels indicating obliterative arteritis are clearly demonstrated at magnification angiography In 2 of the present patients the radiologic appearances suggested chronic rejection, but the clinical diagnosis was acute rejection Both these patients had a normal circulation time and no evident oedema No explanation can be offered for the impression of a general narrowing of the renal arteries Both patients responded well to intensive immunosuppression, and retained good graft function Neither has been re-examined

The demonstration of small intrarenal arteries is improved by magnification angiography to such an extent that the evaluation of the transplanted kidney becomes easier However, the differentiation between tubular necrosis and acute rejection remains uncertain, but further improvement of the technique including use of a 0 1 mm focal spot may be helpful

Addendum in proof

Since the preparation of this communication FOLEY et coll (1975) have reported a reassessment of the role of angiography in the evaluation of post-transplantation dysfunction The diagnosis is based on the angiographic appearance of the cortex using selective magnification technique

SUMMARY

Conventional and magnification angiography were performed on 34 occasions in 31 patients with renal allografts The differential diagnosis between acute rejection and tubular necrosis was uncertain In chronic rejection, where vascular abnormalities dominate, the diagnosis was easier The magnification angiography demonstrated the small intrarenal arteries to better advantage, resulting in a more accurate assessment of the condition

ZUSAMMENFASSUNG

Konventionelle und Vergrosserungsangiographie wurden 34 mal an 31 Patienten mit renalen Allo-Tran...

Abs...

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RESUMÉ

Les auteurs ont fait 34 angiographies simples et avec agrandissement chez 35 malades ayant subi une allogreffe rénale Le diagnostic différentiel entre rejet aigu et nécrose tubulaire était incertain Dans le rejet chronique ou les anomalies vasculaires dominent, le diagnostic était plus facile L'angiographie avec agrandissement montre mieux les petites artères intrarénales, permettant une appréciation plus précise de l'etat du rein

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VASCULAR COMPLICATIONS FOLLOWING NEEDLE PUNCTURE OF THE LIVER

Clinical angiography

C HELLEKANT

Needle biopsy and transhepatic cannulization of blood vessels and bile ducts have for many years been standard methods for the investigation of liver diseases and the reported frequency of complications has been low However, animal experiments have shown that complications demonstrable by angiography may occur after such a puncture consisting of extravasation of contrast medium, hematoma, arteriovenous shunts, vasal occlusions, or aneurysms (HELLEKANT & OLIN 1973) Some of these abnormalities, however, may also be caused by the primary disease, traumatic or malignant

Angiography after biopsy or puncture is consequently necessary to obtain an adequate apprehension of the risk of complications Therefore, it seemed of interest to evaluate such a clinical material in order to assess the frequency and nature of angiographic abnormalities and their importance

Material and Methods

During the years 1971 and 1972 a material of 100 adult patients examined with angiography because of possible liver disease was collected The liver had been

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Table

Frequency of angiographic abnormalities (some patients had several types of abnormalities)

Abnormality	Puncture before angiography (No of patients)	No puncture before angiography (No of patients)
Arteriovenous shunt	15	4
Occluded artery	5	2
Hematoma	4	—
Abscess	1	—
Aneurysm	1	1
Extravasation of contrast medium	4	—
No vascular complication	31	44

punctured for diagnostic reasons before angiography in 51 patients Of these 4 had normal livers, 31 liver malignancy (primary or secondary) and 16 other pathologic liver lesions The remaining 49 patients were used as control and the corresponding figures for their liver lesions were 16, 21 and 12, respectively.

The different types of punctures performed Surgical biopsy on laparotomy in 3 patients, biopsy with a crude needle (diameter 1 2 to 1 4 mm) in 10 patients, percutaneous transhepatic cholangiography with a teflon catheter (diameter 2 2 mm) thread over a puncture needle in 6 patients, aspiration biopsy with a fine needle (diameter 0 7 mm) in 41 patients Of these both the crude and the fine needle had been used in 3 cases, transhepatic cholangiography and fine needle in 3 cases In one case all the different types of punctures had been performed

Angiography was performed with percutaneous catheterization of the femoral artery The catheter was placed in the celiac or superior mesenteric artery depending on the anatomy, in most cases a combined celiac and mesenteric angiography was carried out, in many cases also a selective angiography of the hepatic artery, occasionally with infusion of greater amounts of contrast medium

In all cases biopsy, operation or autopsy or combinations of these methods were performed The liver was considered free of malignancy if autopsy or laparotomy were negative The operation in all cases but 10 was combined with needle biopsy

In 12 patients only needle biopsy with negative result had been carried out All of these patients were alive more than 1½ years after the examination and without signs of liver malignancy One of these patients, however, could not be traced after one year following the angiography This patient had cystic liver disease

Results

Angiography after liver puncture The frequency of angiographic abnormalities appears in the Table All the arteriovenous shunts in this group were arterioportal In 8 cases solitary arterioportal shunts were demonstrated in an area corresponding



Fig 1 Parenchymatous phase of hepatic angiography two days after fine needle aspiration biopsy Subcapsular hematoma (+→) Extravasation to needle tract (—→) (Gas in the bile ducts due to perforation between gall bladder and intestine after cholecystitis) Small hemangioma in the caudal part of the right lobe (⇸)

to the puncture In one case 2 shunts existed in the punctured area Six patients had multiple arterioportal shunts spread out in the liver, these patients had malignant liver tumors, fairly richly vascularized In none of these 6 cases were the shunts combined with other signs of puncture injury Therefore, the shunts were believed to be caused by the tumor and not by the puncture Of the 10 arterioportal shunts with probable correlation with the puncture only one was located in a normal liver and the shunt in that case was combined with an arterial occlusion, extravasation of contrast medium to the needle tract and a large subcapsular hematoma measuring 3 cm 10 cm (Fig 1) A fine needle aspiration biopsy had been performed two days before angiography

Four of the patients with a solitary arterioportal shunt had liver malignancy One of them also had extravasation of contrast medium and a 3 cm × 12 cm hematoma located laterally in the right lobe The patient had Hodgkin s disease with a proved involvement of the liver parenchyma and aspiration biopsy with a fine needle had been performed the day before the angiography

One patient with a widespread growth of poorly vascularized liver metastases from a carcinoma of the gall bladder had an arterioportal shunt in a part of the right

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Fig 3



Fig 4

Fig 3 Hepatic angiography one day after needle biopsy with fine and crude needles in patient with jaundice Transhepatic cholangiography performed one week previously Fairly large arterioportal shunt in the right lobe (→) and smaller one medially in the left lobe (↠) Also a hematoma located laterally in the right lobe

Fig 4 Hepatic angiography in patient with jaundice Transhepatic cholangiography and fine needle aspiration biopsy 5 and 7 days respectively before angiography Also transhepatic cholangiography and several punctures during operation 6 weeks earlier Hematoma located laterally in the right lobe and near the fissure where the vessels are stretched Occluded artery (→) Extravasation of contrast medium (↠)

before angiography, respectively One of them also was punctured with a crude needle 6 days before angiography All 4 had small arterioportal shunts in the right liver lobe The patient who had had a crude needle puncture as well was re examined after 6 months and the shunt was then not demonstrable None of these patients had any other angiographic abnormality which could be related to the puncture

Occluded arteries were seen in one patient with normal liver, in one patient with liver malignancy and in 3 patients with slight fatty infiltration and jaundice, respectively In 2 cases an occluded artery without any other changes compatible with puncture injury was observed, but 2 were combined with subcapsular hematoma and extravasation to the needle tract (Fig 4) In one of these 2 cases a fine needle puncture had been performed 2 days before the angiography and in the other trans-

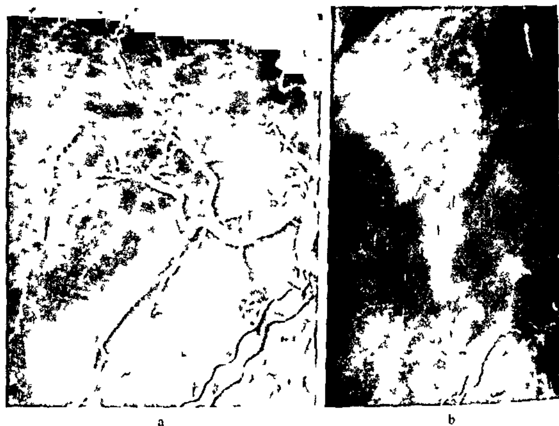


Fig 2 Celiac angiography one month after transhepatic cholangiography in a patient with cholangiocarcinoma a) Arterial phase Arterioportal shunt (→) b) Parenchymatous phase Pooling of contrast medium in sinusoids close to the shunt (↔)

lobe where a fine needle puncture had been made 3 weeks earlier In two cases transhepatic cholangiography had been performed one month and three weeks respectively, before angiography and both had an arterioportal shunt in the vicinity of the catheter which in one of the cases was left in the liver to drain the bile ducts (Fig 2) In one of these patients a repeat angiography was performed after 11 months the shunt was then not demonstrable In the group with other pathologic lesions of the liver than malignancy 5 patients had solitary arterioportal shunts One of them had a slight fatty degeneration of the liver and 4 had jaundice One of the patients with jaundice had a fairly large arterioportal shunt laterally in the right lobe and a smaller one in the medial segment of the left lobe He had also a 3 cm × 10 cm hematoma located laterally in the right lobe (Fig 3) This patient also had an aneurysm with a diameter of 2 cm located proximally on the left gastric artery and another similar aneurysm partly calcified on the splenic artery This patient had undergone transhepatic cholangiography one week before angiography and the liver had been punctured 4 times in order to attain a proper position of the catheter in the bile ducts Biopsy with crude and fine needles had also been made the day before the angiography

The other 4 patients had been punctured with a fine needle 1 7 12 and 21 days

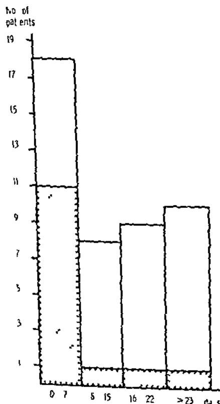


Fig. 6 Vascular complications after liver puncture Time relation (days) between puncture and angiography Six patients with multiple arterioportal shunts combined with liver malignancy but without any other abnormalities indicating a puncture are not included ☐ Total number of punctured patients ⬚ Number of patients with vascular complications

In total, angiographic abnormalities compatible with puncture injury were encountered in 14 of 51 patients

The time between puncture and angiography is given in Fig 6 The six patients with multiple arterioportal shunts combined with liver malignancy are not included in this figure If several punctures had been performed in the same patient, only the one closest to the angiography was noted Of 14 patients with vascular lesions indicating puncture injury, 11 were punctured within a week before the angiography Of the remaining 3 one was punctured with a fine needle 12 days before angiography and had both an arterioportal shunt and an occluded artery One had a fine needle aspiration biopsy 22 days before angiography and had only a minor arterioportal shunt The third was examined with transhepatic cholangiography one month previously and had a rather large arterioportal shunt which, however, was closed at the repeat angiography 11 months later Of the 31 patients without angiographic abnormalities compatible with puncture injury 7 were punctured within one week before angiography, 15 one to three weeks before, and 9 patients more than three weeks before angiography



Fig 5 Parenchymatous phase of hepatic angiography in a patient with jaundice due to pancreatic carcinoma Examination performed 7 days after fine needle aspiration biopsy Operation revealed abscess between liver and abdominal wall Sharp demarcation of the abscess (→)

hepatic cholangiography and a fine needle puncture 5 and 7 days before angiography, respectively This patient had also undergone another transhepatic cholangiography and punctures during operation around 6 weeks earlier

All 4 patients with hematoma had also one abnormality or more compatible with puncture injury None of the hematomas required surgical intervention One patient with an occluded artery also had a lesion appearing as a hematoma located laterally in the right liver lobe (Fig 5) Nineteen days after the puncture this patient was operated upon because of a pancreatic tumor without liver involvement An abscess was found between the lateral edge of the liver and the abdominal wall in a place corresponding to the previous puncture and the angiographic finding Bacterial cultivation showed growth of E coli The abscess was drained and did not require any prolonged healing time

Of the 4 patients with extravasation of contrast medium 3 had other abnormalities compatible with puncture lesions In one case a 5 cm long needle tract within a poorly vascularized tumor was filled without any other signs of puncture injury A hematoma, however, could have been concealed in the vicinity of the tumor No aneurysm was seen within the liver after puncture The observed aneurysm on the left gastric artery had probably another etiology

Discussion

Percutaneous liver biopsy has long been used as a diagnostic tool in liver diseases The most well known methods are those described by SILVERMAN (1938), IVERSEN & ROHOLM (1939) GILLMAN & GILLMAN (1945) and MENGHINI (1958) All these authors have used rather crude needles with diameters up to 2 mm with the intention of obtaining a solid piece of tissue for microscopy Aspiration biopsy with finer needles with a diameter of 0 5 to 1 mm has been described by several authors from LUCATELLO (1895) to SÖDERSTRÖM (1966) and LUNDQVIST (1970, 1971)

For about 10 years percutaneous transhepatic cholangiography has been a well established method in cases with obstructive jaundice (WIECHEL 1964, SELDINGER 1966 MARIONS & WIECHEL 1974)

Reported serious complications after puncture of the liver have been bile leakage into the abdomen or into the blood vessels, intra or extrahepatic bleedings and some cases with pneumothorax (ZAMCHECK & KLAUSENSTOCK 1953, COX 1967, BECKERT 1971 LEVINSON et coll 1972) In extensive materials of transhepatic cholangiography the frequency of complications is around 6 per cent, of these 2 3 per cent is puncture of the wrong organ mostly the gall bladder, and 2 per cent of peritonitis due to bile leakage (WIECHEL)

LINDNER (1971) found a mortality of 0 015 per cent and serious complications in 0 34 per cent of the cases in a material consisting of 79 381 patients who had undergone liver puncture with a crude needle, diameters 1 2–1 8 mm In other smaller series of cases the frequency of serious complications has been higher after crude needle puncture

One serious complication in a total of 2 611 aspiration biopsies with a fine needle was reported by LUNDQVIST (1970) It was an intrahepatic hematoma which required surgical intervention in a patient probably having some defect in the hemostatic mechanism

The number of clinically important complications consequently is low but it is obvious that angiography makes it possible to detect to a greater extent vascular injury after liver puncture There are only few reports dealing with angiography after liver biopsy Cases with arterioportal shunts accidentally discovered on ab dominal angiography have been described by PREGER (1961), ALMÉN & NYLANDER (1965) DEBRAY et coll (1968), TRINEZ et coll (1969), FOLEY et coll (1971) and WALLACE et coll (1972) The last mentioned describe also some cases with aneurysm, demonstration of needle tract and cases with liver hematoma JOHNSON et coll (1968) used scanning to detect a hematoma in the liver after liver biopsy, but most of the cases reported in the literature with bleeding after puncture were discovered on laparotomy or on autopsy (ZAMCHECK & KLAUSENSTOCK, LINDNER 1967, WILTHIRD 1970 BECKERT) Arterioportal shunts were found by MARIONS & WIECHEL in 7 per cent and 3 cases with small aneurysms in a group of 89 patients where angiography had been performed within two weeks after transhepatic cholangiography

The relationship between the type of puncturing instrument and the type of lesion. Of 14 patients with angiographic abnormalities considered caused by the puncture, 8 had been punctured only with a fine needle, 1 with a crude needle and 1 with a cholangiography-instrument A combination of transhepatic cholangiography and fine needle aspiration biopsy was used in 3 cases and of a crude and a fine needle in 1 case No extravasation or hematoma was seen after transhepatic cholangiography only, but in 2 patients where this examination had been combined with another needle puncture A single fine needle biopsy had been performed in 2 cases with large hematomas and in the patient with an abscess

Occluded arteries were demonstrated in 3 cases after a fine needle puncture, in 1 case after a puncture with a crude needle and in 1 case after a combination of trans hepatic cholangiography and fine needle aspiration biopsy

Of 31 patients without any signs of puncture injury, 19 were punctured with a fine needle, 7 with a crude needle or with a combination of crude and fine needle In 3 cases a surgical biopsy was carried out during laparotomy

Condition of the liver parenchyma correlated with angiography Among 31 patients with liver malignancy 5 had signs of puncture injury, and among 16 patients with other pathologic liver lesions, injury was demonstrated in 8 Also 1 of the 4 patients with normal liver parenchyma had vascular abnormalities due to the puncture The distribution of liver malignancy, other pathologic lesions and normal livers was similar among those who were examined with angiography within a week after the puncture and those examined later than one week after the puncture

Angiography without preceding puncture Among the 49 patients, 2 had multiple arterioportal shunts and liver malignancy In 2 patients there was a rapid filling of the hepatic veins, in one case in the whole liver and in the other in the caudal part of the right lobe where several metastases were located The first mentioned had a reticular cell sarcoma in the pancreatic tail without any signs of liver malignancy either at operation or at repeated needle biopsies later on Occluded arteries were found in 2 patients with liver malignancy, in both cases within the tumor masses One patient had a small aneurysm in the liver near the gall bladder The patient had been cholecystectomized several years previously and a resection of the stomach had also been performed

In this group no extravasation or hematoma was demonstrated Arterioportal shunts and artery occlusions were only present together with liver malignancy There was no case with solitary arterioportal shunts of the same type as in the group where puncture preceded the angiography The angiographic abnormalities were found in altogether 5 patients not punctured before angiography Among the other 44, 14 had normal liver, 19 liver malignancy and 11 other pathologic lesions of the liver

Discussion

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The location of all these lesions made it probable that they were caused by the puncture Experiments (HELLEKANT & OLIN) have shown that it is possible to detect vascular injury after liver puncture with angiography in 50 per cent of the animals if the angiography is performed immediately after the puncture The lesions were of the same type as those described from clinical materials except the fact that artery occlusions were absent On repeat angiography after one week pathologic lesions were still found in 6 animals out of 13, but no hematomas were seen

In the present material abnormalities due to puncture were demonstrated in 11 cases of 18 (61 per cent) when angiography was performed within one week Eight of these were examined after 1 to 3 days and the other 3 after 4 to 7 days The fact that only 3 lesions were found in 27 patients where the angiography was carried out later than 1 week after the puncture indicates that the vascular injury heals rapidly Of the remaining 3 arterioportal shunts, 2 were small and 1 was rather large However, even the last mentioned had healed spontaneously after 11 months This may be compared with the result of EKELUND (1971), who reported that 70 per cent of experimentally induced arteriovenous fistulas after renal biopsy in the rabbit closed spontaneously within 2 weeks and that no correlation was found between the size of the fistula and the tendency of healing

The appraisement that an arterioportal shunt had been caused by a puncture was primarily based on the fact that the shunt was located in the proximity of the punctured area Cases with malignant liver tumors and multiple arterioportal shunts were found in both parts of the material Among the patients who had been punctured before angiography some of these shunts could have resulted from the puncture These multiple shunts, however, were located in the vicinity of the richly vascularized tumors and therefore appeared quite different compared with the solitary shunts, all of which were arterioportal One patient who had not been punctured before angiography had a rapid passage of contrast medium into the hepatic veins Also the branches from the left lobe were filled It has not been possible to detect any pathologic lesion in the liver, however The heavy filling of the hepatic veins may be explained by the fact that the patient had a reticulum cell sarcoma in the tail of the pancreas occluding the splenic artery and vein The reduced portal blood flow in combination with the selective injection of contrast medium into the hepatic artery are factors that increase the concentration of the medium in the blood reaching the hepatic vein Particularly heavy filling of the vein from the left lobe is thought to indicate a disturbed portal circulation (GLICKMAN & HANDEL 1972)

Another patient had a rapid local shunting of contrast medium into the hepatic veins Such shunts are not common but may be found in cases with richly vascularized metastases This patient had such metastases from a carcinoma of the colon

Arterioportal shunts do not influence the systemic circulation on account of the filtering effect of the liver sinusoids (MOONEY et coll 1970) Such influence occurs, however, in cases with intrahepatic arteriovenous shunts due to Osler's disease If a wide arterioportal shunt remains open for a long time, portal hypertension may

develop (FOSTER & SANDBLOM 1961, TREDE et coll 1969) and SCHILLING (1953) experimentally demonstrated that fatty infiltration and focal fibrosis develop after creation of arterioportal fistulas

The majority of the arterioportal shunts in the present material have been small A few were rather large, but none has been considered to be important The great difference in frequency between early and late angiography indicates that most of the shunts close spontaneously The hematomas have been rather large but in no case was surgery indicated However, several cases are reported in the literature where the bleeding has been fatal In a survey ZAMCHECK & KLAUSENSTOCK found bleeding to be the cause of death in 30 of 39 reported cases, but in the majority of these cases no attention had been paid to the hemostatic mechanisms Nowadays it is believed that a defect in that mechanism contraindicates a liver puncture

GOTHLIN & TRANBERG (1973) reported a case of liver abscess requiring operation after transhepatic cholangiography Also in the present material there was a patient with an abscess along the lateral border of the liver after puncture, on angiography interpreted as a hematoma All the hematomas, however, were less well demarcated from the liver parenchyma and therefore a differentiation now seems possible

[illegible] hem were peripheral and pro-

[illegible] The punctured patient had an aneurysm on the left gastric artery which was well within the reach of the 20 cm long cholangiography instrument The examination had been difficult to perform and 4 punctures had been made A relation between the puncture and the aneurysm is possible but the combination with an aneurysm on the splenic artery suggests that degenerative disease is the cause One of the patients not punctured before the angiography had a small aneurysm near the gall bladder, similar to experimentally induced aneurysms (HELLEKANT & OLIN) and possibly caused by previous operations

MENGHINI (1970) believes that the frequency of complications is related to the diameter of the needle the time that the needle is inside the liver, and the skill of the operator The cholangiography instrument is the crudest used in the present material and the procedure takes more time than a biopsy It is also sometimes necessary to make more than one puncture to obtain a correct position of the instrument The use of a catheter diminishes the risk of rupture of the capsule, but when the catheter is left for drainage the liver parenchyma is exposed to the foreign material for a fairly long time

According to these criteria the risk of serious complications should be greatest with transhepatic cholangiography On the other hand, on needle biopsy tissue is removed from the liver

The present results do not allow a statement that a crude needle is more dangerous than a finer one Even if a correlation between needle diameter and risk of complication is probable it is notable that 2 of our patients developed large liver hematomas

after fine-needle aspiration biopsy and that another one had extravasation of contrast medium into the needle tract The patient with an abscess also was punctured with a fine needle

The condition of the liver parenchyma seems to be of less importance Among 47 patients with liver disease 13 had angiographic abnormalities suggesting puncture injury, and one case among the 4 with normal parenchyma had such an abnormality It is noteworthy that *among 9 patients with jaundice, as many as 6 presented injury* after the puncture In three of these, however, combinations of fine needle biopsy and transhepatic cholangiography or a crude needle biopsy had been performed

SUMMARY

Angiography after liver puncture was performed at different intervals in 51 patients Fourteen cases had abnormalities believed to be caused by the puncture Most of these were small but there were also 4 cases with large liver hematomas and 1 case with an abscess between the liver and the abdominal wall, none requiring acute surgery Several arterio-portal shunts were demonstrated but seemed to close spontaneously No certain correlation between the severity of the injury and the diameter of the puncture instrument could be assessed

ZUSAMMENFASSUNG

Es wurde eine Angiographie zu verschiedenen Zeitpunkten nach einer Leberpunktion bei 51 Patienten vorgenommen Vierzehn Falle wiesen Abweichungen auf, von denen angenommen wird, dass sie durch die Punktion hervorgerufen worden sind Die Mehrzahl dieser Abweichungen waren geringfugig, es fanden sich jedoch auch 4 Falle mit grossen Leber-Hamatomen und 1 Fall mit einem Abszess zwischen der Leber und der Abdominalwand, keiner forderte akute Chirurgie Es wurden verschiedene arterio-portale Shunts nachgewiesen, die sich jedoch spontan zu schliessen schienen Es bestand keine sichere Korrelation zwischen dem Umfang der Schädigung und dem Diameter des Punktionsinstrumentes

RÉSUMÉ

L'auteur a fait une angiographie après ponction hépatique à différents intervalles chez 51 malades Il a observé des anomalies qu'il pense dues à la ponction dans 14 cas La plupart de ces anomalies étaient peu importantes mais il y avait aussi dans 4 cas de gros hématomes hépatiques et dans un cas un abcès entre le foie et la paroi abdominale Aucun de ces cas n'a nécessité une intervention chirurgicale d urgence Plusieurs shunts artério portaux ont été mis en évidence mais il semble s etre fermes spontanément L auteur a pu établir une certaine corrélation entre la gravité de la lésion et le diamètre de l instrument de ponction

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EFFECTS OF EMULSIFIED IODO-LIPIDS

A toxicologic investigation in the rabbit

C HELLEKANT and T OLIN

The base for a sucessful surgery of the liver is a detailed and reliable morphologic diagnosis Conventional angiography is sometimes insufficient especially at small poorly vascularized tumours BECKERMAN & POPKEN (1938) used an emulsion called Jodsol (DEGKWITZ 1938) to perform hepatography The toxicity was, however, relatively high (OLSSON 1941) Recently iodized fatty acid emulsions have been developed in France for radiography of the liver (LAVAL-JEANTET et coll 1972) It was therefore thought worthwhile to evaluate their effects on some of the body functions

Material and Methods

Two different emulsions (Guerbet, France) were used The first one consisted of one part AG 52 315 and two parts glucose solution 5 5% shaken by hand for one minute The size of the oil droplets was ≥15 μm and the iodine content 160 mg/ml The second emulsion was called AG 60 99 The size of the droplets was about 1 μm and the iodine content 200 mg/ml It was sterile and stable if kept in a refrigerator

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Table 1

Neurotoxicity of emulsions AG 60 99 and AG 52 315

Emulsion	Dose ml	No of animals	Injection site	Blood brain barrier lesion
AG 60 99	10	2	Intravenously	0
	10	2	Superior mesenteric artery	0
	10	1	Internal carotid artery	+ + +
	5	2	Internal carotid artery	+ +
	2 5	1	Internal carotid artery	+ + +
	1 25	1	Internal carotid artery	+ +
AG 52 315	10	2	Superior mesenteric artery	0
	10	2	Internal carotid artery	died
	10	1	Intravenously	0

Twenty-five rabbits weighing about 2 0 kg were used and the effect of the emulsion on the brain, the heart, the kidney, the liver and the general circulation was analyzed

Neurotoxicity The behaviour of 12 rabbits was observed after injection of the emulsion in various vascular territories (Table 1) Ten ml of the small particle emulsion (AG 60 99) were injected intravenously into 2 animals and 10 ml of the coarse emulsion (AG 52 315) were injected into one rabbit A similar dose of the two emulsions was injected into the superior mesenteric artery in 4 animals Selective injection into the internal carotid artery was performed in 7 animals by the method of JEPPSSON & OLIN (1970) In 3 of these animals 10 ml of the emulsion were injected and the behaviour of the animals was observed but in the remaining 4 the effect on the blood-brain barrier was recorded after 5 0, 2 5 and 1 25 ml of Ag 60 99, respectively The injection was made with an infusion machine (CLEMENTZ & OLIN 1961) at a constant rate of 0 16 ml/s Following completion of the injection of the emulsion, a solution of ypan blue was infused intravenously and 10 minutes later the circulation was rinsed with physiologic saline, followed by fixation in formaldehyde The brain was then removed, macroscopically inspected and microscopy was performed (JEPPSSON 1962)

Cardiotoxicity During selecti e injection of the emulsion into the right and left coronary arteries the arterial blood pressure was monitored and the ECG recorded in 5 rabbits A catheter (OPP 10, Portex, England, OD/ID 0 65/0 25 mm) was introduced into the right common carotid artery and its bent and tapered tip introduced into the decided coronary artery, aided by magnification fluoroscopy (CARTER & OLIN 1973), 0 4 to 0 9 ml emulsion was injected by hand at different injection rates

Nephrotoxicity The emulsion was selectively injected into the renal artery in 3 rabbits The following parameters were measured arterial blood pressure, cardiac

output renal blood flow the extraction of ^{51}Cr EDTA and ^{125}I Hippuran by the kidney and the haematocrit The cardiac output was measured by the dye dilution technique 0 6 ml of indocyanine green solution (about 1 mg/ml) was injected into the right superior caval vein as a bolus while arterial blood from the common carotid artery was sucked through a spectrophotometer The unilateral renal blood flow was measured by a similar dye dilution technique 0 10 ml of the dye solution was injected into the renal artery through a catheter from the femoral artery while blood from the renal vein was sucked through the spectrophotometer The signal from the spectrophotometer was recorded on a dual channel potentiometer writer (EKELUND et coll 1972 LYRDAL & OLIN 1975) The flow was calculated according to the Stewart Hamilton formula as applied by LINGARDH et coll (1969) ^{51}Cr EDTA and ^{125}I Hippuran in isotonic glucose were given as a priming dose followed by a slow even infusion The concentrations of the nuclides were measured in arterial blood and in renal vein blood in a dual channel scintillation detector and the extraction (E) was calculated according to the formula

$$E = \frac{A - V}{A - b}$$

where A is the concentration of the nuclide in arterial blood V the concentration in the renal vein blood and b is the background The overlap between the two channels was adjusted for The haematocrit (Hct) was determined with a micromethod The clearance (Cl) was calculated according to the formula

$$Cl = RBF \times E \times (1 \quad Hct)$$

where RBF = the renal blood flow (ml/min)

Before the effects on the body functions were recorded conventional films were exposed and urography was performed

Haemodynamics and liver toxicity Emulsions were injected into the superior mesenteric artery or the portal vein in 8 rabbits The arterial blood pressure the portal pressure and the cardiac output the elimination of indocyanine green in the liver the ESR the haematocrit and the viscosity of the blood were measured The portal pressure was measured in some of the animals by a cannula in the superior mesenteric vein and in some animals by a catheter in a wedged position in one of the hepatic veins The cardiac output was measured by the dye dilution technique as described under nephrotoxicity The elimination of indocyanine green in the liver was determined in the following way The cardiac output was first determined by an intravenous injection and sampling on the arterial side then a similar amount of indicator was injected in the portal vein Due to the elimination of some of the indocyanine green in the liver only a reduced amount of the indicator passed to the general circulation The two measurements were made at short intervals and the cardiac output was considered to be stable Since following the injection into the portal

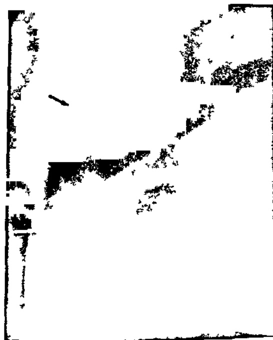


Fig 1 Radiography of the heart, lateral projection following injection of 0 9 ml coarse emulsion into the right coronary artery Uptake of emulsion in the anterior wall of the right ventricle

vein some of the indocyanine green is eliminated at the passage through the liver, the Stewart-Hamilton dilution curve will be smaller in proportion to the elimination in the liver which thereafter may easily be calculated The ESR was measured with a micro-method The viscosity of the blood was measured when the blood was perfused at a constant speed through a micropore filter and the perfusion pressure measured by an electromanometer (SWANK et coll 1964)

Results

Neurotoxicity The results are presented in Table 1 No neurologic reactions whatsoever were observed in any of the animals following injection of the small particle emulsion (AG 60 99) in a dose up to 10 ml No lesions to the blood brain barrier occurred when the injection was made intravenously or into the superior mesenteric artery If, however, the injection was made selectively into the internal carotid artery, injury occurred at doses of 5 0, 2 5 and 1 25 ml When the coarse emulsion (AG 52 315) was injected into the superior mesenteric artery in a dose of 10 ml, no neurologic reactions were encountered and no lesion to the blood brain barrier occurred When, however, this emulsion was injected selectively into the internal carotid artery, the animals died quietly

Cardiotoxicity At slow injection of AG 60 99 in increasing doses, 0 4, 0 6 and 0 9 ml, alternating into the left and right coronary artery, no reactions appeared At rapid injections into the left coronary artery, the largest dose, 0 9 ml, caused a strong blood pressure fall, the emulsion accumulated in the wall of the left ventricle

Table 2

Renal blood flow of the left kidney (RBF) cardiac output, extraction (E) of EDTA, glomerular filtration rate, extraction (E) of Hippuran and haematocrit before and after 2 ml kg body weight of AG 60 99 injected selectively into the left renal artery

	Before	After
Cardiac output, ml/min	580	520
RBF, ml/min	70	76
Per cent of cardiac output	12	15
E_{EDTA} per cent	29	25
Glomerular filtration rate, ml/min	11 6	11 2
$E_{Hippuran}$ per cent	71	63
Haematocrit, per cent	43	41

Table 3

Renal blood flow of the left kidney (RBF) cardiac output, extraction (E) of EDTA glomerular filtration rate extraction (E) of Hippuran and haematocrit before and after 2 ml/kg body-weight of emulsion (one part AG 52 315 and two parts glucose 5.5 %) injected selectively into the left renal artery

	Before	After 5 min	After 60 min
Cardiac output ml min	610	530	530
RBF, ml min	72	37	52
Per cent of cardiac output	12	7	10
E_{EDTA} per cent	16	9	8
Glomerular filtration rate ml/min	7 3	2 1	2 6
$E_{Hippuran}$ per cent	67	69	43
Haematocrit per cent	37	36	37

Table 4

Renal blood flow of the right and left kidneys (RBF), cardiac output, extraction (E) of EDTA glomerular filtration rate, extraction (E) of Hippuran and haematocrit nine days after 2 ml/kg body-weight of emulsion (one part AG 52 315 and two parts glucose 5.5 %) injected selectively into the right renal artery

	Right kidney	Left kidney
Cardiac output ml min	470	580
RBF ml/min	64	74
Per cent of cardiac output	14	13
E_{EDTA} per cent	18	19
Glomerular filtration rate ml min	8 0	9 7
$E_{Hippuran}$ per cent	68	63
Haematocrit per cent	31	31

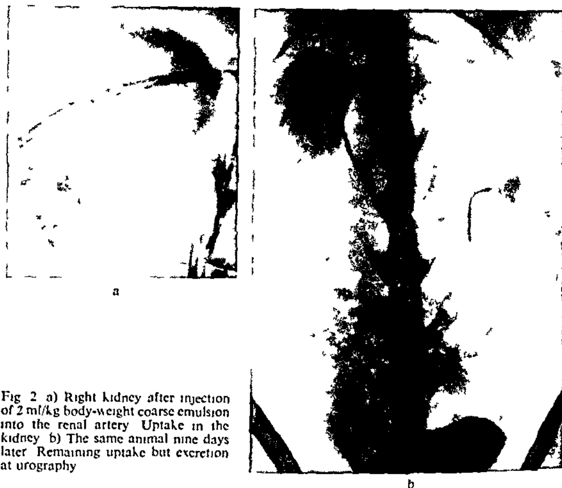


Fig 2 a) Right kidney after injection of 2 ml/kg body-weight coarse emulsion into the renal artery Uptake in the kidney b) The same animal nine days later Remaining uptake but excretion at urography

and ECG suggested an infarct but no fibrillation was recorded When 0 4 0 6 and 0 9 ml of the coarse emulsion was slowly injected into the coronary arteries, the blood pressure fell at each injection At the highest dose, ECG suggested a large infarct, followed by death of the animal in ventricular fibrillation about 10 minutes later (Fig 1) No ECG abnormalities were observed following selective injection of either of the emulsions into the superior mesenteric artery at a dose of 2 ml/kg body-weight

Nephrotoxicity Following selective injection of AG 60 99 into the renal artery of one rabbit, the arterial blood pressure, cardiac output, renal blood flow and the extractions of Cr-EDTA and I-Hippuran were unaffected (Table 2) The emulsion passed straight through the kidney to the renal vein No embolization was revealed

In another rabbit 2 ml/kg body-weight of the coarse emulsion were injected into the left renal artery (Table 3) The emulsion accumulated in the kidney The renal blood flow diminished to about half of the previous values as did the extraction of EDTA The extraction of Hippuran was initially unchanged but later on it diminished considerably

Table 5

Cardiac output, liver extraction (E) of indocyanine green, portal pressure, arterial blood pressure, ESR, and haematocrit before and after 2 ml/kg body weight of emulsion AG 60 99 injected selectively into the superior mesenteric artery

	Before	After	After 10 ml of dextran
Cardiac output, ml/min	480	380	410
$E_{indocyanine\ green}$ per cent	52	0	0
Portal pressure, mm Hg	10	14	15
Arterial pressure, mm Hg	175/130	135/120	140/100
ESR	2	2	—
Haematocrit, per cent	47	47	—

Table 6

Cardiac output, liver extraction (E) of indocyanine green, portal pressure, arterial blood pressure, ESR, and haematocrit before and after 2 ml kg body weight of emulsion (one part of AG 52 315 and two parts glucose 5.5 %) injected selectively into the superior mesenteric artery

	Before	After	After 10 ml of dextran
Cardiac output, ml min	490	420	430
$E_{indocyanine\ green}$ per cent	59	0	0
Portal pressure, mm Hg	9	14	15
Arterial pressure, mm Hg	165/115	150/115	145/100
ESR	2.5	2	2.5
Haematocrit, per cent	41	46	40

In a third rabbit, 2 ml/kg body-weight of the coarse emulsion were injected into the right renal artery (Fig 2 a), 3 days later the emulsion was still accumulated in the kidney At urography, however, there was visible excretion Nine days after the injection of the emulsion, uptake still existed in the kidney and the renal blood flow and the renal function were determined (Table 4, Fig 2 b) No significant difference between the two kidneys was recorded and the values were normal

Haemodynamics and liver toxicity The haemodynamic changes following injection of 2 ml/kg body weight of the emulsions, selectively into the superior mesenteric artery appear in Tables 5, 6 and Figs 3, 4 The reactions on both emulsions were about the same The cardiac output and the arterial blood pressure fell while the portal pressure increased by almost 50 per cent The changes were usually slightly more evident with the coarse emulsion than with the small particle emulsion Determination of the ESR and viscosity of the blood performed through a micropore



Fig. 2. a) Right kidney after injection of 2 ml/kg body-weight coarse emulsion into the renal artery. Uptake in the kidney. b) The same animal nine days later. Remaining uptake but excretion at urography.

and ECG suggested an infarct but no fibrillation was recorded. When 0.4, 0.6 and 0.9 ml of the coarse emulsion was slowly injected into the coronary arteries, the blood pressure fell at each injection. At the highest dose, ECG suggested a large infarct, followed by death of the animal in ventricular fibrillation about 10 minutes later (Fig. 1). No ECG abnormalities were observed following selective injection of either of the emulsions into the superior mesenteric artery at a dose of 2 ml/kg body-weight.

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a



b

Fig 3 a) Hepatography after injection of 2 ml/kg body weight coarse emulsion into the superior mesenteric artery b) Specimen Stasis of emulsion in the small portal branches

filter revealed no signs of sludge The elimination of indocyanine green in the liver fell from around 60 per cent to nil If dextran was administered in a dose of 5 to 30 ml, the cardiac output was restored completely or partially but the portal pressure still remained elevated

Discussion

The effect on the brain of the emulsions depended upon the site of the injection At injection into the superior mesenteric artery no injury to the blood brain barrier



Fig 4 a) Hepatography after injection of 2 ml/kg body weight small particle emulsion into the superior mesenteric artery Homogeneous uptake in the liver b) Specimen The portal branches contrasting against the liver parenchyma

occurred even when the coarse emulsion was used If the injection was made directly into the internal carotid artery however the animals immediately died when the coarse emulsion was used The small particle emulsion caused no evident neurologic signs but lesions to the blood brain barrier appeared These lesions were severe in the dose range 5 to 1 25 ml with no major difference at different dose levels and might be due to the surface active agents stabilizing the emulsion The droplets are small enough to pass the capillaries The fact that no lesion to the blood brain

barrier and no neurologic signs were observed after injection into the superior mesenteric artery is in accordance with the absence of neurologic symptoms and signs in patients after similar injections in a dose of 0 5 to 0 8 ml/kg body weight (LAMARQUE 1974, LAMARQUE et coll 1973)

The small particle emulsion will pass through the coronary circulation at slow injection rates without causing any adverse reactions At rapid injection rates, however, severe reactions developed The cardiotoxicity at direct injection into the coronary artery was obviously relatively low for the small particle emulsion and high for the coarse emulsion

The *nephrotoxicity revealed similar conditions* The small particle emulsion passed the renal circulation while the coarse emulsion embolized the kidney Surprisingly enough renal function was completely restored with time even when the uptake of the emulsion in the kidney still remained THEANDER & WEHLIN (1962) tried another emulsion (LBg 21) to improve the venous phase at nephroangiography, but found that even moderate quantities injured the kidney

Following selective injection into the superior mesenteric artery both emulsions passed the small bowel circulation and were captured in the liver, resulting in a 'hepatography' When the coarse emulsion was used the appearance was mottled suggesting that the medium was located to the sinusoids (Fig 3) Microscopy, however, revealed emulsion in the fine portal branches The mottled appearance is obviously due to superimposition of these structures When the small particle emulsion was used the uptake was homogeneous (Fig 4) The blockage in the liver raised the portal pressure while the cardiac output and the arterial blood pressure usually diminished somewhat, presumably due to impaired venous return A plasma expander such as dextran may compensate this

The liver function as judged by the elimination of indocyanine green is severely impaired by both emulsions The manufacturer (GUERBET 1973) has reported that microsomal enzymes are deliberated from the liver GOT was slightly raised and normalized after a few days, the GPT and LDH were normalized between 3 and 6 days after the injection of the small particle emulsion, suggesting a transient injury to the liver

At an injection into the superior mesenteric artery small amounts of emulsion might accidentally pass to the aorta and be drained into the renal arteries But, even at injection of a great amount of coarse emulsion into one of the renal arteries the injury was reversible Such an accident may be prevented if the injection is controlled by fluoroscopy The capillary filter in the liver including the reticulo-endothelial system seemed to have satisfactory capacity to prevent injury to the brain or the heart, as no lesion occurred after injection into the superior mesenteric artery In mice 80 per cent of the small particle emulsion was found in the liver following injection into the portal system (GUERBET) The capillary filter of the lungs might also be of some help After intravenous injection of the coarse emulsion in mice 62 per

cent was captured in the lungs LD_{50} at intravenous injection in mice is 7 2 g iodized oil/kg body-weight as coarse emulsion, and 8 5 g as small particle emulsion, corresponding to 16 ml of emulsion The LD_0 for the latter is 9 ml/kg body weight

Small particle oily emulsions have since several years been used for nutrition purposes in humans without severe adverse reactions (SCHUBERTH 1963) The iodized fat in the tested emulsions, is probably similar to the nutritional emulsions The iodine is split off and excreted in the urine, and the fat combusted in the body Therefore, hypersensibility to iodine must be considered as a contraindication for examination with radiographic emulsions The injection site was of high importance for the toxic reactions The safest injection place is probably the superior mesenteric artery as three filters are interposed in front of the general circulation the big capillaries of the bowel, the liver, and finally the lungs Highest uptake in the liver is obtained by injection of the coarse emulsion into the superior mesenteric artery, but it is essential that there is no spill over into the aorta In spite of the acute toxic effect on the liver, it is considered justifiable to use the media for clinical hepatography when there is a shortcoming of conventional angiography

SUMMARY

Two different iodized oil emulsions have been intravascularly injected into rabbits one with a particle size of 15 μm or more and one with a size of about 1 μm The effects of the emulsions have been evaluated on the brain the heart the kidney, the liver and the circulation The reactions to the small particle emulsion was minor, especially if administered slowly The injection site was of critical importance The safest place for injection was the superior mesenteric artery If supplied directly to the brain or the heart the emulsions were often deleterious particularly the coarse one

ZUSAMMENFASSUNG

Es wurden zwei verschiedene jodhaltige Öl Emulsionen Kaninchen [illegible]
[illegible]
Die sicherste Stelle fur die Injektion war die obere Mesenterial Arterie Die Emulsionen waren oftmals schädlich, besonders die grobe, wenn diese direkt dem Gehirn oder dem Herzen zugefuhrt wurden

RESUMÉ

[illegible] étudié les effets de ces émulsions sur le

cerveau, le cœur, le rein, le foie et la circulation Les réactions à l'émulsion à particules fines ont été minimes, en particulier si l'émulsion est injectée lentement Le lieu de l injection a une grande importance L'artère mésentérique supérieure est le lieu d injection le moins dangereux Si elles sont administrees directement au cerveau ou au cœur, ces emulsions ont été souvent nuisibles, en particulier l'émulsion à grosses particules

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ARTHROGRAPHY OF THE KNEE

II. Isolated and combined lesions

H G RINGERTZ

During the five-year period 1965 1969, 2 836 arthrographies of the knee were performed, of these 1 349 were regarded as radiologically abnormal The essential types of lesions registered, concerned menisci, collateral and cruciate ligaments. Classification of the findings and the frequency of various lesions have been presented in Part I (RINGERTZ 1973), as well as the sex distribution in the material and the abnormalities in the statistical panorma of lesions assembled over 25 years In the present report, isolated and combined lesions will be analysed in an attempt to give a radiologic explanation and systematization of the biomechanism of the underlying trauma Previously such an analysis was done from combined surgical and biomechanical aspects by SMILLIE (1973) All of the functional units of *the knee* joint explored by him and reported in an extensive survey of injuries to the knee joint cannot, for practical reasons, be included in calculations based on an arthrographic material only Thus, for example, *ruptures of the* lateral collateral ligament and, in part, also of the superficial fibres in the medial collateral ligament have been incompletely accounted for On *the other hand*, retrospective statistical analyses of an arthrographic material can be made without bias and in great detail

The anatomic and physiological definition of the knee joint and its movements are well described by SMILLIE

Submitted for publication 9 December 1974

Table 1

The sites of the lesions within the menisci in the subsets of isolated and combined meniscus lesions

	Subset							
	1		4		5		7	
	No of cases	Per cent	No of cases	Per cent	No of cases	Per cent	No of cases	Per cent
	294	(100)	202	(100)	129	(100)	189	(100)
Rupture or operation								
medial meniscus only	237	(81)	170	(84)	105	(81)	147	(78)
both menisci	7	(2)	4	(2)	9	(7)	24	(13)
lateral meniscus only	50	(17)	28	(14)	15	(12)	18	(10)
Ruptures within the medial meniscus								
anterior part	84	(29)	75	(37)	44	(34)	44	(23)
middle part	151	(51)	125	(62)	67	(52)	104	(55)
posterior part	169	(57)	111	(55)	69	(53)	137	(72)
Ruptures within the lateral meniscus								
anterior part	42	(14)	22	(11)	19	(15)	19	(10)
middle part	43	(15)	24	(12)	15	(12)	28	(15)
posterior part	17	(6)	5	(2)	6	(5)	19	(10)

Subset 1 Isolated meniscus lesions
4 Combined meniscus and collateral ligament lesions
5 Combined meniscus and cruciate ligament lesions
7 Combined meniscus and collateral and cruciate ligament lesions

Material and Methods During the period, 1 349 (47 per cent) of all knee arthrographies performed in the department were regarded as radiologically abnormal As has been described in Part I, the material was divided into 8 subsets depending upon prevailing isolated or combined lesions of menisci and ligaments These subsets were (1) meniscus lesion alone, (2) collateral ligament rupture alone, (3) cruciate ligament rupture alone, (4) combined meniscus and collateral ligament lesions, (5) combined meniscus and cruciate ligament lesions, (6) combined collateral and cruciate ligament ruptures, (7) combinations of (1) (2) and (3), (8) other findings only, (1) to (3) have been designated isolated and (4) to (7) combined lesions For further details regarding case material and methods, see Part I

Results

The localization of meniscus lesions to side and part of meniscus The material has been statistically classified to make it possible to analyse the site of rupture from several aspects The location in the medial or lateral meniscus, the site and frequency

Table 2

Relation between localization of the meniscus lesions and the percentage of combined meniscus and ligament ruptures Percentage values given in the first column refer to the totals and the percentage values in the other columns refer to corresponding number in the first column (Triplicate lesions have not been tabulated)

	No of cases	Per cent	Combined rupture of medial collateral ligament		Combined rupture of cruciate ligament					
					Anterior rupture, degree*					Posterior rupture
			No of cases	Per cent	1	2	3	Total	Per cent	
					No of cases					No of cases
Localized meniscus lesion	757	(100)	361	(48)	100	90	83	273	(36)	8
medial meniscus only	613	(81)	298	(49)	82	76	58	216	(35)	7
both menisci	34	(4)	21	(62)	8	5	11	24	(71)	0
lateral meniscus only	110	(15)	42	(38)	10	9	14	33	(30)	1
Lesions of different parts of the medial meniscus	647	(100)	319	(49)	90	81	69	240	(37)	7
anterior only	36	(6)	13	(36)	3	4	1	8	(22)	0
middle only	78	(12)	38	(49)	10	5	3	18	(23)	0
posterior only	154	(24)	71	(46)	17	23	21	61	(40)	2
anterior + middle	47	(7)	20	(43)	6	3	3	12	(26)	1
anterior + posterior	10	(2)	6	(60)	1	1	1	3	(30)	0
middle + posterior	168	(26)	91	(54)	28	24	22	74	(44)	3
anterior + middle + posterior	154	(24)	80	(52)	25	21	18	64	(42)	1

* 1 = overstretched
2 = subtotally ruptured
3 = totally ruptured

of the lesions with reference to the anterior, middle or posterior location, and the extent of each individual lesion

In Table 1, the number of cases with injury or operation on the medial, lateral or both menisci is given These cases have been subdivided into the appropriate subsets of meniscus ruptures The number of injuries to each of the different parts of the medial or lateral menisci within each subset also appears Cases of meniscectomy have been excluded from the statistics concerned with the affected parts of menisci In addition, the number of cases in the entries has been given as a per cent of the total number of cases in the respective subsets The total number of cases with localized meniscus lesions is presented in the first column of Table 2 *Distribution of* the lesions as a function of their extent within the medial meniscus in each individual case has been included as well (cf Fig 1) The lower portion of Table 2 thus includes

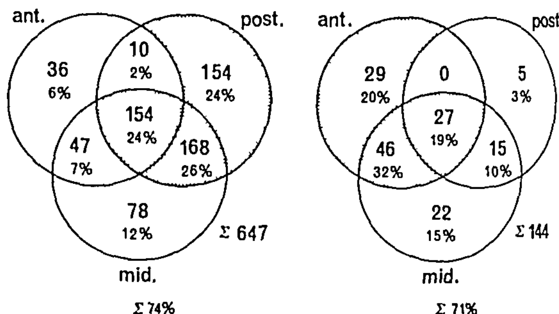


Fig 1 Extent of lesions in medial (left) and lateral (right) meniscus The circles in the Venn diagrams represent anterior, middle, and posterior parts of the meniscus Number of cases of a given extension is indicated, together with percentage in the appropriate field The three sites of highest relative frequencies on each side are dotted and the sum of these frequencies in each meniscus is given below

injuries to the medial meniscus in patients with isolated medial or both medial and lateral meniscus lesions

The following columns present the number and percentage of cases in the first column having additional ligament ruptures Cases from subsets (4), (5) and (7) are included, since the table is designed to illustrate the connection between rupture of the ligaments and the site of the meniscus lesion With injury of the anterior ligament, the subdivision has been extended further by the specification of different degree of rupture

A further analysis of the 34 cases with coexisting medial and lateral meniscus lesions has been made The calculations cover the type and site of meniscus injury No difference has been found between this group and the larger group of cases with either medial or lateral ruptures When the analyses were broadened to cover the ligament ruptures as well, an increased frequency was evident in the group with coexisting lesions the 71 per cent of anterior cruciate ligament ruptures in this group is a highly significant difference ($p < 0\ 001$) from the remainder of the cases The corresponding increase to 62 per cent of additional medial collateral ligament ruptures is not significant ($p = 0\ 1$)

A calculation of the significance of the connection between rupture of the medial collateral ligament and injuries of the attached middle part of the medial meniscus was made All lesions of the medial meniscus involving the middle part have been compared with all other meniscus lesions regarding the frequency of coexisting in-

juries of the medial collateral ligament The difference found, 51 and 42 per cent respectively, is significant ($p<0.05$)

The percentage of injuries within each third of the meniscus was calculated in the subsets (1), (4), (5) and (7) On the medial side, the values are 46, 51, 47, and 50 per cent, respectively The corresponding figures in the lateral meniscus are 12, 8, 10, and 12 per cent

A comparison between the extent of the lesions in the medial and lateral menisci is presented in Fig 1 The circles in the Venn diagrams represent the anterior, middle and posterior parts of the meniscus The upper common area with a low frequency of lesions for example, represents the discontinuous rupture of the anterior and the posterior parts of the meniscus not involving the middle part The three combined sites having the highest relative frequency in each of the diagrams have been dotted, and their percentage total is given in the diagram The demonstrated difference in the distribution of lesions on the medial and lateral sides is highly significant ($p<0.001$)

A rupture of semilunar cartilage involving the posterior, or the posterior and middle parts, or the whole meniscus may be said to be consistent with extension of the injury from behind and forward The inverse is true for a rupture extending from the front and backward Ruptures involving the entire menisci are thus consistent with both categories and have been excluded when comparing the two groups

On the medial side, the site of the lesions is selectively consistent with a direction from behind in 187, and from in front in 63 cases, a dominance which is further strengthened with coexisting cruciate ligament rupture The proportion of 75 per cent from behind cited above, increases to 87 per cent, or 135 and 20 cases, respectively

On the lateral side, the opposite is true 50 cases against 8 favours a direction of the meniscus lesion from the front when no concomitant cruciate ligament lesion exists Inclusion of such a lesion reduces this 86 per cent dominance to 68 per cent (25 cases against 12) The dominance for a direction of the rupture from behind is significant on the medial side and from the front on the lateral side ($p<0.01$ and $p<0.05$, respectively) The differences with and without coexisting cruciate ligament injury are also significant both on the medial ($p<0.01$) and lateral side ($p<0.05$)

Types of meniscus lesions The four types of meniscus lesions vertical, oblique, horizontal and multiple have been summarized in Table 3 and distributed among the subsets of injuries to the semilunar cartilages As these types have been assessed separately for the three different parts of each meniscus, the assessment of injured meniscus sites is presented in the table Figures for the total number of meniscus parts refer to each meniscus and total three times the number of cases in each subset The corresponding multiplication is not valid for the number of injured meniscus parts for a couple of reasons For example, different types of lesions may occur in different parts of the same meniscus

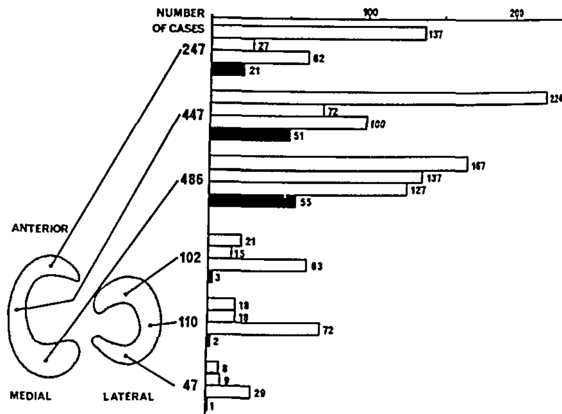


Fig 2 Types of meniscus ruptures present in the three parts of the medial and lateral meniscus Each bar and figure represents the number of cases of a certain rupture type at a certain site Rupture type Vertical ▭ oblique ▭ horizontal ▭ multiple lesions ■

The division of the types of lesions present in the different parts of the menisci has been analysed The entire material as presented in the last column of Table 3 was the basis for the calculations The results appear in Fig 2 On the medial side the vertical rupture dominates in all sites, as does the horizontal rupture on the lateral side A vertical rupture is most common in the middle part of the medial meniscus and occurs in any part of the medial semilunar cartilage in 40 per cent of all meniscus lesions On the lateral side, this rupture and the oblique lesion are equally frequent and together constitute 6 per cent of all meniscus lesions The corresponding value for the oblique type on the medial side is 17 per cent The horizontal rupture is most common in the posterior part of the medial meniscus Regardless of location on the medial side, this type of rupture exists in 20 per cent of all meniscus injuries, and on the lateral side in 12 per cent On the lateral side it occurs most frequently in the middle part of the meniscus

All the percentages apply to the number of cases of a given type of rupture in any part of the meniscus, thus one and the same case may be included in more than one group if different types of lesions are present in different parts of the meniscus There is a highly significant difference ($p < 0.001$) in the distribution of the different subsets of the types of ruptures on the medial and lateral side (Table 3)

Table 3

Distribution of different types of meniscus ruptures in the subsets of isolated and combined lesions The number of injured meniscus parts in each group are given together with percentage of the totals at the medial and lateral side

	Subset								Total	
	1		4		5		7		No	Per cent
	No	Per cent	No	Per cent	No	Per cent	No	Per cent		
Examined meniscus parts at each side	882		606		387		567		2 442	
Injured parts, medial meniscus	404	(100)	311	(100)	180	(100)	285	(100)	1 180	(100)
vertical	130	(32)	152	(49)	79	(44)	167	(59)	528	(45)
oblique	114	(28)	50	(16)	38	(21)	34	(12)	236	(20)
horizontal	122	(30)	68	(22)	46	(26)	53	(19)	289	(24)
multiple	38	(9)	41	(13)	17	(9)	31	(11)	127	(11)
Injured parts lateral meniscus	102	(100)	51	(100)	40	(100)	66	(100)	259	(100)
vertical	20	(20)	11	(22)	5	(13)	11	(17)	47	(18)
oblique	14	(14)	11	(22)	5	(13)	12	(18)	42	(16)
horizontal	63	(62)	28	(55)	30	(75)	43	(65)	164	(63)
multiple	5	(5)	1	(2)	0		0		6	(2)

Subset 1 Isolated meniscus lesions
4 Combined meniscus and collateral ligament lesions
5 Combined meniscus and cruciate ligament lesions
7 Combined meniscus and collateral and cruciate ligament lesions

Lesions of the collateral ligaments Lesions of the collateral ligaments were found in 771 cases 51 and 40 per cent were combined with meniscus and cruciate ligament ruptures, respectively These figures include 25 per cent with combinations of all three types of lesions

Among all 814 cases of injuries to the meniscus, 391 (48 per cent) were combined with a rupture of a collateral ligament The corresponding value for the 531 cases of cruciate ligament lesions was 306 (58 per cent) Out of 318 cases with both meniscus and cruciate ligament injury, 189 (59 per cent) also had collateral ligament ruptures

Table 4 demonstrates the distribution of the site of the medial collateral ligament lesion in the appropriate subsets A contrast leakage involving both the femoral and tibial parts of the ligament occurred in only 1 out of 263 isolated ligament ruptures The corresponding number in the subsets with combined lesions is 12 cases out of 508 The difference is significant ($p<0\ 05$)

When the meniscus rupture is associated with a lesion in the tibial part of the

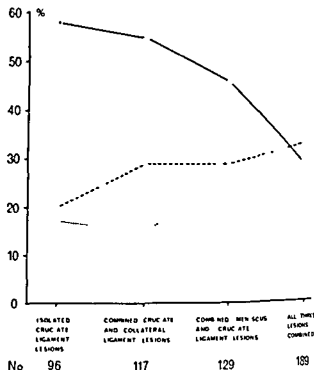


Fig 3 Distribution of the different degrees of cruciate ligament lesions in appropriate subsets Percentage fractions have been plotted for each subset Points representing same degree of rupture have been joined — overstretched, --- subtotally ruptured, totally ruptured cruciate ligament

medial ligament, 74 per cent of the meniscus tears are vertical The combination with a rupture at the femoral end of the ligament includes 52 per cent vertical meniscus lesions These percentages are significantly higher than the 32 per cent of vertical tears in subset 1 with isolated meniscus injuries

Lesions of the cruciate ligaments Ruptures of the cruciate ligaments existed in 531 cases, 9 involved both ligaments and 11 only the posterior ligament, 60 per cent were combined with meniscus tears and 58 per cent with rupture of a collateral ligament Included in these percentages are 36 per cent of the cases where the cruciate ligament lesion was combined with both the other types of injuries In all 814 cases with meniscus lesions, 318 (39 per cent) were combined with cruciate ligament rupture Corresponding value for the 771 cases with collateral ligament lesion was 306 (40 per cent) Of the 391 cases with both meniscus and collateral ligament injuries, 189 (48 per cent) also had cruciate ligament ruptures

The distribution of the different degrees of cruciate ligament lesions in the appropriate subsets is presented in Fig 3 The percentage division of these degrees of rupture has been plotted for each subset The points representing the same degree in different subsets have then been joined more or less horizontally The order of the subsets along the X-axis is such that the least complicated injuries (subset 3) are at the left and the most complicated (subset 7) are at the right The order between subsets (5) and (6) has been chosen in such a way as to make the curves as continuous as possible

Table 4

Frequency of different sites of collateral ligament ruptures in the appropriate subsets

	Subset 2		4		6		7	
	No of cases 263	Per cent	No of cases 202	Per cent	No of cases 117	Per cent	No of cases 189	Per cent
Medial collateral ligament								
femoral part	249	(95)	188	(93)	110	(94)	171	(90)
both parts	1	(0)	5	(2)	2	(2)	5	(3)
tibial part	11	(4)	9	(4)	4	(3)	12	(6)
Lateral collateral ligament	2	(1)	0		1	(1)	3*	(2)

* of which 2 also had a rupture of the femoral part of the medial collateral ligament

Subset 2 Isolated collateral ligament rupture
4 Combined meniscus and collateral ligament lesions
6 Combined collateral and cruciate ligament rupture
7 Combined meniscus collateral and cruciate ligament lesions

A separate analysis of the subsets of cruciate and collateral ligament ruptures shows that tibial lesions of the latter are independent of the degree of the cruciate ligament injury

A selective analysis of the 20 cases with ruptures of the posterior cruciate ligament was undertaken, and the result appears in Table 5 In subset 3 with isolated cruciate ligament lesions 8 cases (8 per cent) have posterior ruptures, while the remaining 12 cases (3 per cent) are distributed on subsets (5) (6), and (7) This difference is significant with $p<0 01$

Discussion

In the large published materials on arthrography of the knee, there are significant statistical differences both *in essential and detailed findings* There are many explanations for these differences, but *generally* speaking an analysis of the mere incidence does not *directly* reveal the fundamental aspect, which is the knowledge of the biomechanical mechanisms which are disclosed by the statistical figures.

Numerous difficulties are met with in a statistical analysis, one being that lesions may arise at varying times as a result of either multiple trauma or because one injury may in the long run predispose a second, another is the often encountered disparity between surgical and radiologic findings Some differences result from the limited radiologic possibility to draw a conclusion about the extra articular structures. One more problem is the limitation placed by surgical technique on the surgeon's estimate of the type and extent of the lesion

Table 5

Radiologic findings in 20 cases of ruptures of the posterior cruciate ligament

	Case number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total (per cent)
Rupture degree																					
1 – overstretched															×	×	×	×	×	×	30
2 – subtotally ruptured							×	×	×	×	×	×	×	×							40
3 – totally ruptured	×	×	×	×	×	×															30
Isolated rupture						×							×	×					×	×	25
Combination with rupture of																					
anterior cruciate ligament with degree	2			2			1	1			2	1			1	3	2				45
medial collateral ligament rupture																					
femoral part	×	×			×		×	×	×	×	×	×			×						50
tibial part	×	×	×				×														20
medial meniscus	×	×	×				×	×	×	×	×							×			45
lateral meniscus							×														5
fracture				×							×										15
capsular rupture									×							×					10

In the present material, the *amount of statistical data gathered* has been so comprehensive that only parts of the results *are presented*

The *injuries* analysed here may be caused by different types of trauma with isolated or combined forces involved These forces are (1) longitudinal compression, (2) abduction, (3) adduction, (4) flexion, (5) extension, and (6) rotation In the normal function of the knee, all except (2) and (3) are included In order to cause an injury the remaining strains must be combined or must markedly exceed normal stress

Meniscus lesions The isolated meniscus lesion often represents the initial result of a relatively mild injury, limited to this lesion Theoretically it may be caused by all the mentioned forces The isolated lesion has, however, on the whole, the same appearance and statistical distribution of site and type as should apply to the other meniscus injuries

The appearance is dominated by three types of lesions (SMILLIE), most common is the longitudinal rupture of the medial meniscus In his material of 4 500 operated menisci (1958–1968), medial menisci appeared in 31 per cent as compared with 57 per cent in this report (Fig 2), if the vertical and oblique ruptures are added The horizontal ruptures at the medial and lateral sides were the second and third lesions with respect to frequency, 20 and 12 per cent, respectively The corresponding fre-

quency in SMILLIE's material are 52 and 9 per cent Thus the figures do not coincide Various, partially technical explanations for the disparities are possible One is that some of the oblique ruptures which in the present material have been included with the vertical ruptures have from the surgical point of view been estimated as predominantly horizontal Another reason may be the higher frequency of vertical medial ruptures in younger patients, as pointed out by SMILLIE This fact should give a higher frequency of vertical, medial ruptures in the present material where the average age is 29 6 years against 38 4 calculated for SMILLIE's 4 500 cases The higher frequency is partially confirmed by findings in children (STENSTRÖM 1968)

The ratio between lateral and medial meniscus lesions is 1 4 6 in the whole material and 1 4 3 for the isolated meniscus lesions In SMILLIE's material (8 000 operated menisci), the ratio is 1 2 5 PARRY et coll (1958) report a relationship of 1 2 in a material from England In Japan this ratio (AMAKO 1960), amounts to between 1 9 and 1 4 In children a ratio between 1 3 3 and 1 1 was found (STENSTRÖM p 72) The reason for this disparity is not obvious and unlikely to be explained by minor differences in anatomical structure ' (SMILLIE) One possibility could be that the varying symptomatology of the lesion results in surgical decisions which differ in different parts of the world Another factor might be that the arthrographic technique makes certain types of lesions in some parts of the menisci easier to overlook than in other parts

Ruptures in both menisci are said to occur in 2 5 per cent (LINDBLOM 1948) and in children in 3 per cent (STENSTRÖM) In the present series (Table 2), this frequency was 4 per cent or 34 cases In this group, the type and localization of meniscus and medial collateral ligament lesions coincided with other published series, while a highly significant over representation of cruciate ligament lesions was found Most probably a cruciate ligament lesion secondary to changed weight bearing conditions predisposes to concomitant medial and lateral meniscus lesions (SMILLIE) The connection between medial collateral ligament ruptures and lesions in the middle part of the medial meniscus is statistically significant The underlying mechanism could imply either isolated abduction force a rebound trauma, or maximal rotation

There is a highly significant difference between the distribution of lesions in the medial and lateral menisci (Fig 1) The shadowed spaces in the Venn diagram, which represent the three most common types of meniscus lesions, indicate that ruptures run from behind and forward on the medial side, and in the reverse direction on the lateral This difference is significant on statistical analysis The findings on the lateral side contradict the results based on a considerably smaller material of OLSON (1967) The accepted, most frequent mechanism of injury to the medial side is the inward rotation of the femur (SMILLIE) The most common rupture direction in the menisci should thus accord with the direction in which the tibial condyles move in relation to the menisci during the screw home rotation

The distribution of different rupture types through the parts of both menisci, (Fig 2), displays different appearances on the medial and lateral sides On the medial

side, the vertical meniscus rupture is dominant, while laterally an even more sig nificant dominance exists for the horizontal rupture That relationship has bee pointed out by RICKLIN et coll (1971) among others On both sides the multipl rupture type is rare, while the two remaining rupture types occur about equally fre quently on each side In part the above differences in the incidence of medial an lateral lesions between the present material and reports in the literature arise from tech nical problems in radiographic demonstration of vertical lateral ruptures obscure by vertical contrast structures

The incidence of different types of meniscus lesions in the subsets on the later side is about equal On the medial side a clear tendency exists, first of all, wit respect to the vertical meniscus lesions They increase from 32 per cent in the grou of isolated meniscus lesions to close to 60 per cent in the cases with 'O'Donoghue triad,' i e combined lesions of the medial meniscus, collateral ligament, and anteric cruciate ligament The remainder of the lesions are present in equal frequency c decrease accordingly (Table 3)

Medial collateral ligament The classification of the medial collateral ligamer lesions used corresponds mainly with that proposed by PALMER (1938) These lesion result principally from abduction forces which first produce an isolated lesior Secondary to a stronger force, the anterior cruciate ligament becomes involved Th resulting combined lesion includes a partial rupture of the anterior cruciate ligamer (PALMER) This corresponds with the situation demonstrated in Fig 3 Consequently the subset with combined ligament lesions has the lowest percentage of totally rup ture cruciate ligaments Concomitant lesions in the proximal and distal parts of th collateral ligament are very unusual (Table 4) Their significantly lower incidenc among the isolated ligament lesions indicates a connection with the trauma mecha nism involved in the origin of combined lesions

There is a tendency to more frequent lesions in the tibial part of the collatera ligament with increased complexity of the lesion This relationship is probably sec ondary to the anatomic and mechanical interplay involved in the vertical rupture of the middle part of the medial meniscus which is strongly overrepresented in th more complex combined lesions

Anterior cruciate ligament Lesions of the anterior cruciate ligament form one o the three large injury groups in this material, occurring in 39 per cent of all lesions

From SMILLIE it may be calculated that he observed ruptures of the anterior cruciat ligament in 8 per cent of 7 500 menisectomies The discrepancy between his figur and that in the present material remains unchanged even if the occurrence of th anterior cruciate ligament lesions is expressed in percentage of the sum of cases i subsets containing meniscus lesions instead of in relation to the total number o cases This is a most serious lesion, since it is easily overlooked at surgery becaus of the difficulty of diagnosing these injuries either clinically or by arthrography (LILJEDAHL et coll 1966)

In the present report the grading of cruciate ligament injuries has been done in greater detail than previously, which results in improvement of the statistical possibilities (Fig 3)

Opinions may differ as to whether the continuity of the curves demonstrates significantly that the combination of meniscus and cruciate ligament injury results from greater traumatic force than that causing combined collateral and cruciate ligament lesions This may be explained by the fact that locking secondary to medial meniscus lesions may cause a rupture of the anterior cruciate ligament

Posterior cruciate ligament Rupture of the posterior cruciate ligament is an unusual knee joint injury Lately, however, it has been discussed (TRICKEY 1968, LILJEDAHL & NORDSTRAND 1969) Thus a compilation has been done of the 20 cases (1 5 per cent) included in the present material (Table 5)

In the group of isolated cruciate ligament lesions, this lesion is over-represented, compared to the groups of combined lesions This corresponds to a trauma towards the upper part of tibia with the knee flexed

SUMMARY

The findings in 1 349 abnormal cases out of 2 836 arthrographies of the knee have been evaluated statistically Isolated and combined lesions of menisci, medial collateral and cruciate ligaments have been compared Type and degree of the individual lesion change with increased *complexity of* combined injuries A sequential grading for some lesions has been established A dominant direction of rupture was found differing in the medial and lateral meniscus Vertical ruptures and ruptures of the posterior part of the medial meniscus were positively correlated to more complex injuries

ZUSAMMENFASSUNG

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RÉSUMÉ

L auteur a fait u...
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... des ligaments croisés Le type et le degré des

lésions de chacune de ces formations changent à mesure qu'augmente la complexité des lésions associées L'auteur a établi une gradation séquentielle pour certaines lésions Il a trouvé une direction dominante de la rupture qui est différente dans le ménisque interne et dans le ménisque externe Les ruptures verticales et les ruptures de la partie postérieure du ménisque interne sont en corrélation positive avec des lésions plus complexes

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RADIOGRAPHIC MEASUREMENTS OF THE RADIO-CARPAL JOINT IN NORMAL ADULTS

SVEN FRIBERG and BO LUNDSTRÖM

For the analysis of the distal radial fractures, 'fractura radii typica', Colles' fracture, a correct measurement of the angle between the articular surface of the distal end of the radius and the long axis of the bone in both the frontal (postero-anterior) and the lateral projections is of major importance The distance between two perpendiculars to the long axis of the radius, one drawn through the tip of the styloid process of the radius and the other tangential to the distal articular surface of the ulna, has also been shown to be of value in this connection. Further, it has been suggested that the relationship between the ulnar part of the articular surface of the radius and the ... of malac ... series pe ... relationship between the therapeutic results after treatment of radial fractures and the measured radiographic displacements in the fracture have been published (NISSEN-LIE 1939, LIDSTRÖM 1959, FRYKMAN 1967) However, the normal values for the parameters used to assess the position of the distal articular surface of the radius have only seldom been discussed (KEATS et coll 1966) ... from a recommend ... the textbooks in diagnostic radiology give no explicit

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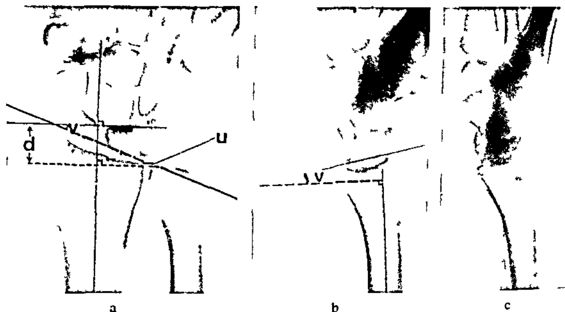


Fig 1 P a and lateral views of a normal wrist with rel marked out Central ray a) perpendicular to the film t film The articular surface of the radius is more dist d distance between the ulnar articular surface and a process of the rad us u = distance between the plane of the ulnar articular surface and a parallel plane through the ulnar part of the radial articular surface

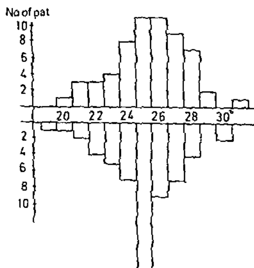
instructions on the technique of examining the distal articular surface of the radius This must indicate that a direction of the ray at right angles to the object and film is generally considered to be optimum both for frontal and lateral projections The articular surface of the radius is, however, not perpendicular to the long axis of the bone but is inclined both in the ulnar and volar directions It may therefore be ex pected that non perpendicular projections might give a better reproduction of the articular surface and possibly yield different values for the parameters measured

Therefore, it was considered to be of interest to evaluate the reliability of radio graphic measurements of the radio carpal joint on films taken with the central ray perpendicular to the radius and on films taken with the central ray directed proximally in order to follow the joint surface more closely

Materials and Methods

Sixty radio carpal joints have been examined in 50 adults (30 males and 20 females) Only wrists of patients without a history of fracture or joint disease were included in the assessment Both joints were examined in 5 males and 5 females

Radiographic technique A skull table (Elema Schonander) with a film focus distance of 70 cm was used The wrists were examined in p a and lateral projections with a vertical ray direction The arm was abducted 90 degrees at the shoulder joint and flexed 90 degrees at the elbow In the p a projections the palm of the hand was



placed against the film and 2 views were taken with centering towards the radio-carpal joint, one with the central ray at right angles to the film and one with the central ray directed 10 degrees proximally In lateral projections the hand was held in exact position by a special immobilizing device, one film was exposed with the central ray at right angles to the film and one with the central ray directed 15 degrees proximally Only views in which the ulna was superimposed on the radius were accepted as true lateral views

Measuring technique In p a views the articular surface of the radius is defined by 2 contours a less easily defined peripheral one representing the dorsal margin of the articular surface and a more clearly defined proximal contour representing its volar margin (Fig 1) As measuring points were selected the radial and ulnar corners of the latter contour and a line representing the plane of the articular surface was drawn through these points A line representing the plane of the articular surface of the radius was drawn in a similar manner on the lateral film The long axis of the radius was defined by a line drawn through 2 points located in the middle of the diaphysis of the radius at distances of 3 cm and 6 cm proximal to the joints The inclination of the articular surface was then expressed as the angle measured between the lines representing the articular surface in the p a and lateral projections and a line perpendicular to the long axis of the radius Further, a measurement was made of the distance between the plane of the articular surface of the ulna and a plane through the tip of the styloid process of the radius Finally, an assessment was made of the relationship between the articular surfaces of the ulna and the radius by measuring the distance between 2 lines drawn at right angles to the long axis, one tangential to the articular surface of the ulna and the other to the ulnar edge of the articular sur-

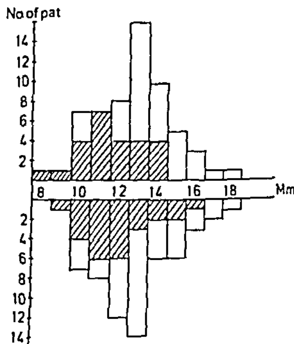


Fig 3 The distance from the plane of the articular surface of the ulna to a plane through the tip of the styloid process of the radius M − 12 8 mm SD − 2 3 mm On an average, the distance was 1 7 mm shorter for females than for males Top central ray perpendicular projection, bottom central ray directed 10° prox ▭ Male ▨ Female

face of the radius All measurements were performed independently by each author, and the means of these measurements are reported

Statistical methods The variance and standard deviation of the measurements were calculated for each projection The F-test has been used to assess differences between the groups

Results

Postero-anterior projection

The central ray at right angles to the film The range of the ulnar inclination was 20 to 30° The mean value was 25 4° and the standard deviation 2 2° No difference was found between the sexes The distance d (see Fig 1) averaged 12 8 mm for the complete series (range 8 to 18 mm) The mean value was lower for women than for men, measuring 11 6 mm for women and 13 6 mm for men (Fig 3) The distance u (Fig 1) averaged 0 3 mm, standard deviation 1 7 mm

The central ray directed 10 degrees proximally No significant difference was found between the values measured on films exposed with this ray direction compared with those measured on films taken with perpendicular ray direction The mean value for the ulnar inclination of the articular surface of the radius was 25 0° (range 19 to 30°) and the standard deviation 2 2 mm (Figs 2, 3)

Lateral projection

The central ray at right angles to the film The measuring points of the articular surface were difficult to define The mean value for the inclination of the plane of the articular surface was 14 5° (range 4 to 22°), and the standard deviation was 4 3°

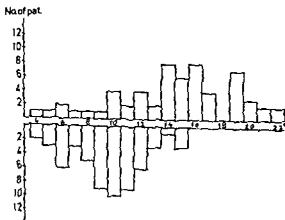


Fig. 4 Volar inclination of the articular surface of the radius top central ray perpendicular bottom central ray directed 15° prox. M = 14 5° and 9 3 respectively SD = 4 3 and 2 7°, respectively

(Fig 4) The individual measurements of the two authors resulted in different values, average difference 3 2° No difference was found between the sexes

The central ray directed 15 degrees proximally In this projection the mean value for the volar inclination was 9 3° (range 4 to 15°), and the standard deviation 2 7° (Fig 4) The measuring points were easy to define and the difference in the values measured by the authors averaged 1 5° The statistical assessment of the variances revealed a highly significant ($p < 0.005$) increase in exactitude when the central ray was directed proximally compared with the perpendicular one

Bilateral measurements

For all projections except the perpendicular lateral one a comparison of the values obtained for the inclination of the articular surface of the radius showed an average difference of 1° between the two wrists of the same individual The perpendicular lateral projection resulted in an average difference of 4° between the two sides The lateral difference for the distance *d* averaged 1 0 mm and for u 0 7 mm The results are summarized in the Table

Discussion

The results reveal that lateral views taken with the central ray directed 15 degrees proximally yielded significantly higher exactness in measurements of the volar inclination of the distal radial joint surface compared with a projection with the central ray perpendicular to the forearm The reason for this is to be found in the fact that a perpendicular projection is not tangential to the joint plane and therefore will yield less easily defined measuring points than the other projection

The different projections were also found to give different values for the volar inclination of the articular surface The mean value was 9 degrees for the view taken with a proximally directed beam and 15 degrees for the perpendicular one This dif

Table

Results of the measurements

Ulnar inclination		
Central ray perpendicular	25 4°	SD 2 2 (range 20° to 30)
Central ray directed 10° prox	25 0°	SD 2 2 (range 19° to 30°)
Volar inclination		
Central ray perpendicular	14 5°	SD 4 3° (range 4° to 22°)
Central ray directed 15° prox	9 3°	SD 2 7 (range 4° to 15°)
The distance d (see Fig 1)		
Central ray perpendicular	12 8 mm M 13 6 mm F 11 6 mm	SD 2 3 (range 8 to 18 mm)
Central ray directed 10° prox	12 8 mm M 13 3 mm F 12 0 mm	SD 2 3 (range 9 to 18 mm)
The distance u (see Fig 1)		
Central ray perpendicular Mean	−0 32 mm	SD 1 7 (range +3 mm to −4 mm)
Central ray directed 10 prox Mean	−0 13 mm	SD 1 58 (range +4 mm to −3 mm)

(+u = the ulnar articular surface distal to, and −u proximal to the radial articular surface)

ference in mean values is explained by the anatomy of the distal radial joint surface, which in itself is concave and consists of several smaller concavities with different orientation in space

Other projections could be used for radiography of the radio carpal joint but on experimenting with different directions of the rays it was found that a projection with the central ray directed 15 degrees proximally produced the most practical view demonstrating both the articular surface and the distal part of the radius A direction of 25 degrees has been recommended previously (Parker & Culpepper 1946, Lidstrom) This projection, however, will give a distorted view of the distal part of the radius and does not seem to have been put into practical use

Most authors indicate a mean of 9 5° to 12° for the volar inclination of the articular surface (Nissen-Lie, Gartland & Werley 1951, Lidstrom, Golden 1963, Frykman, Rochlin & Zeitler 1968) Based on measurements in 50 adults Keats et coll stated a volar inclination of 6 degrees as the normal value for males and 3 degrees for females They also indicated a range of variation from 11° volar to 4° dorsal inclination These values were probably based on measurements on films taken without a proximally directed central ray Their figures deviate quite considerably from the present values Wiklund & Mullern-Aspegren (1956) reported that the normal volar inclination varied between 5 and 15 degrees and Gartland & Werley reported that the normal range in their series was 1 to 21 degrees In other reports a range is seldom given

In the present material the ulnar inclination of the articular surface of the radius

was found to be 25° ± 2 2° (range 19 to 30°) without any significant difference between the projections or between the sexes This accords with the values published previously (NISSEN LIE, WIKLUND & MÜLLERN ASPEGREN, GOLDEN) The relationship (d) between the styloid process of the radius and the distal articular joint line of the ulna was slightly greater in men than in women, the difference being 2 mm The mean value for males as well as females was the same in both of the projections used 12 8 mm (range 8 to 18 mm), which agrees with previous reports (NISSEN LIE, LIDSTRÖM)

HULTEN found that, on an average, the distal articular surface of the ulna projected 0 087 mm proximally to the ulnar part of the articular surface of the radius with a standard deviation of 1 12 mm These results differ only slightly from the present 0 3 mm It should be noted, however, that the standard deviation is somewhat higher (1 7 mm) in the present material

A comparison of the parameters measured in both wrists of the same individual shows that there are only small differences between the right and left wrists Thus, if necessary, values from one joint may be used as norms for assessing the other joint of the same individual

The main result of the present measurements was that a lateral view taken with the central ray directed 15 degrees proximally gives considerably better defined measuring points and, consequently, a better basis for assessing the volar inclination of the articular surface plane

SUMMARY

Radiography of 60 normal wrists was performed in 50 adults to determine the inclination of the distal joint surface of the radius The central ray was directed 10 degrees proximally in postero-anterior projection and 15 degrees proximally in lateral pro ect on The
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exactness o ... value for the volar inclination was 9° in the latter projection

ZUSAMMENFASSUNG

Röntgenuntersuchung 60 normaler Handgelenke wurde bei 50 Erwachsenen vorgenommen um die Neigung der distalen Gelenkoberfläche des Radius zu bestimmen Der Zentralstrahl war 10 Grad proximal bei postero-anteriorer Projektion und 15 Grad proximal bei lateraler Projektion gerichtet Die erhaltenen Werte wurden m t denen
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RÉSUMÉ

Les auteurs ont fait des radiographies de 60 poignets normaux chez 50 adultes pour mesurer l'inclinaison de la surface articulaire distale du radius Le rayon central a été incliné de 10° en direction proximale en incidence postéro-antérieure et de 15° en direction proximale en projection de profil Les valeurs obtenues ont été comparées avec celles fournies par des incidence perpendiculaires On n'a pas constaté de différence entre les 2 projections postero antérieures, dans la projection de profil, avec une inclinaison proximale du rayon central les points de mesure sont mieux définis, donnant une augmentation significative de l'exactitude des mesures La valeur moyenne de l'inclinaison radiale est de 9° dans cette dernière projection

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SPINAL CORD VASCULARITY

III. The spinal cord arteries in man

LEON TVETEN

The first detailed descriptions of the vascular anatomy of the human spinal cord were published by DURET (1873), ADAMKIEWICZ (1881, 1882) and KADYI (1889) Since then a large number of reports, extensively covered in more recent monographs (CORBIN 1961, JULIAN 1965, JELLINGER 1966, PISCOL 1972) have appeared, and the findings of the pioneers have mainly been confirmed Most of these investigations have been based on cadaver dissections and injections of colouring agents into the arteries of the isolated cord, suitable for gross analyses, but not wholly adequate for a detailed appraisement of the microscopic arrangement of small arteries and the capillary bed Modern methods of radiography and microangiography have rendered possible more exact and detailed evaluation of the vascular architecture (TURNBULL et coll 1966, HASSLER 1966)

However, although certain facts about the spinal cord vascularity seem to be well established, contradictory information on essential details may be found in the literature

Thus, GILLILAN (1958), contrary to TURNBULL et coll stated that the radicular arteries which join the arterial trunks of the spinal cord are different from other root arteries, in that they have no branches and are not concerned with the supply of the roots

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LAZORTHES et coll. (1966 a) maintained that the great radicular artery of the lumbosacral cord (the artery of Adamkiewicz) always gives rise both to a large anterior and a large posterior root artery. JELLINGER believed that the two feeders are most often separated while CORBIN and CLEMENS (1966) did not accept the existence of a particularly large feeder to the dorsal aspect of the cord.

Further, NOESKE (1958) and CLEMENS described and named three pairs of longitudinal arterial trunks on the lateral aspect of the cord, in addition to the single anterior and the paired posterior spinal arteries which are commonly accepted.

The functional significance of the pial arterial plexus as an anastomotic pathway between the anterior and the posterior spinal arteries has also been a matter of great dispute. TURNBULL et coll. stated that the size of the pial arteries often depicted in previous diagrams is greatly exaggerated. They believed, contrary to ADAMS & VAN GEERTRUYDEN (1956) and CORBIN but in accordance with GILLILAN and GARLAND et coll. (1966), that the pial arteries provide only a limited number of anastomoses between the longitudinal trunks.

Most authors agree that arterial anastomoses above the capillary level do not occur within the parenchyma of the spinal cord. In a recent paper, however, FAZIO & AGNOLI (1970) claimed that the central cord arteries interconnect both in the depth of the anterior median fissure and within the spinal cord forming longitudinal anastomotic channels which extend the entire length of the cord and, further, that the right and the left halves of the spinal cord segment are connected by transverse branches from the central arteries.

Finally, ROLL (1958) and later CLEMENS have described arteriovenous anastomoses on the surface of the lumbosacral cord. ROLL considered this feature essential in regulation of the spinal cord blood flow. However, their findings have not yet been confirmed.

The main intention of the present work was to investigate: (1) the arrangement of arterial tributaries to the spinal cord, their regional distribution and the incidence of significant anterior and posterior root arteries branching from a common stem, (2) the arrangement of the surface arteries of the cord, the longitudinal arterial trunks and the pial arterial plexus, (3) the branching of the intramedullary arteries, whether anastomotic connections between the central arteries do exist, inside or outside the spinal cord.

Material and Methods

The material comprised the spinal cord from 30 human infants used in a previous report of the extraspinal arteries (TVETEN 1976).

Three specimens were excluded from the material due to deficient filling of the radicular arteries or the surface arteries of the cord. The remaining 27 specimens all displayed good filling of large arteries on and within the spinal cord, while filling of small arteries, arterioles and capillaries varied to some extent in individual cases and also in different regions of the cord in others. In a few the contrast medium had

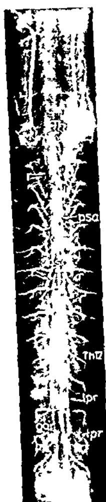


Fig 1

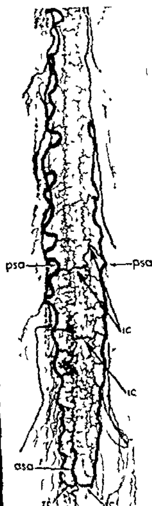


Fig 2

Fig 1 Angiography of decalcified speci men with intact spinal cord Origin and arrangement of arterial tributaries (r) to the thoracolumbar cord The great anterior radicular artery (gar) at L2 on the right side

... position of the specimen only The anterior (asa) and the posterior (psa) spinal arteries

Fig 2 Transparent spec men ...

penetrated into the veins as well It is well known that filling of the minute blood vessels post mortem is a capricious task (TURNBULL et coll)

The cords were subjected to radiography and made transparent according to methods described previously (TVETEN)

The examinations were performed with the whole specimens placed in different positions and on sections of the cord cut in the transverse and longitudinal planes into pieces from 2 to 5 mm thick Some of these pieces were embedded in paraffin wax, sectioned at about 20 μ, mounted on slides, and cleared for microscopy of the capillary network

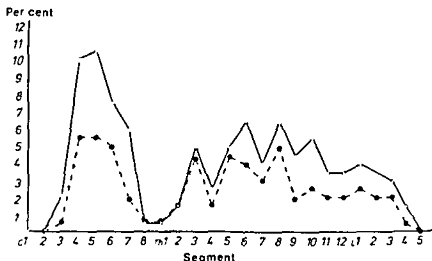


Fig 3 Segmental distribution of the anterior root arteries (● left, ○ right, Δ total) in per cent of the total number in 27 humans

Results

The radicular arteries

Significant root arteries, i e those seen on gross examination joining the surface arteries of the spinal cord, travelled along the ventral aspect of the anterior and the posterior nerve roots, respectively The roots themselves were supplied mainly from small branches of the spinal artery outside the dura mater or occasionally from descending branches of the pial arterial plexus or twigs from the anterior and posterior spinal arteries extending to the rootlets

The incidence of significant single ventral and dorsal spinal cord tributaries branching from a common stem varied from 1 to 8 in individual cases, averaging 3 to 4, and was higher in the cervical region than in other parts of the spinal cord Division of the common stem occurred immediately outside the dura mater (Fig 1)

The anterior radicular arteries joining the anterior spinal artery varied considerably in size, number and location in individual cases Only those visible on gross examination of the cord were counted Their total number varied from 3 to 15 in individual cases—averaging 7 Different regions of the spinal cord received a varying number of arteries, the cervical region 1 to 6, average 3, the thoracic region 1 to 5, average 3 to 4, and the lumbar region 0 to 4, average 1 In about half of the cases no significant ventral radicular artery was observed in the lumbar region The upper two thirds of the cervical enlargement (C4–C7) were more lavishly supplied than any other part of the spinal cord In the cervical region the arteries entered from the left as frequently as from the right side while in the thoracic and the lumbar region there was a predominance of vessels from the left side (Fig 3) Arteries entering the same spinal cord segment from both sides occurred most often in the cervical region, predominantly at the C4 and C5 segments The paucity of anterior radicular arteries

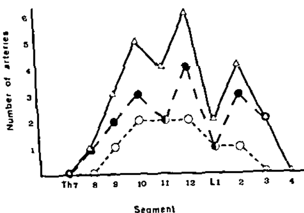


Fig 4 Location of the great anterior root artery of Adamkiewicz in 27 humans (Symbols as in Fig 3)

in the upper thoracic cord was striking As demonstrated in a previous report (TVETEN), this region corresponds to a large extent to the distribution area of the superior intercostal artery from the costocervical trunk

The position of the great anterior radicular artery (the artery of Adamkiewicz) varied from Th8 to L3 (Figs 1, 4) In about half of the cases it followed the lower thoracic nerve roots (Th10–Th12) while a lumbar origin was observed in about one third of the specimens Most often it was the only ventral feeder to the lower thoracic and lumbosacral cord In about one fourth of the cases one small artery—rarely two—was seen at levels below the entrance of the great anterior radicular artery The additional supply to the lumbosacral cord was mainly found in cases with a high (thoracic) position of the Adamkiewicz's artery In approximately one third of the specimens the great anterior radicular artery came from a common stem with a posterior radicular artery that joined the posterior spinal artery

The posterior radicular arteries were smaller in width but more numerous and more evenly distributed (Fig 5) As for the anterior radicular arteries, however, there was a minimum of supply to the upper thoracic cord Individually the number of posterior radicular arteries ranged from 14 to 25, averaging 19 to 20 The figures from the different regions were, cervical region 3 to 8, average 7, thoracic region 6 to 14, average 10 lumbar region 1 to 6, average 2 to 3 Not infrequently the arteries were found at the same level on both sides Such an arrangement varied individually from 2 to 9 pairs averaging 5 pairs and this was most frequently encountered in the cervical region Occasionally the posterior radicular artery in the lumbar region appeared to be larger than others in the series but it was never so prominent as the great anterior radicular artery (Fig 1)

The surface arteries of the spinal cord

The anterior spinal artery was formed rostrally by the union of the anterior spinal rami from the intracranial parts of the vertebral arteries It extended without inter-

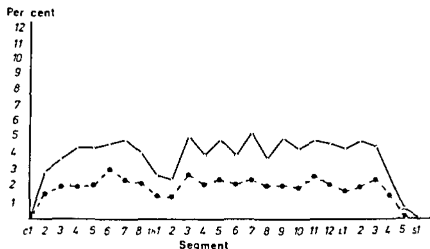


Fig 5 Segmental distribution of the posterior root arteries in per cent of the total number in 27 humans (Symbols as in Fig 3)

ruption in front of the anterior median fissure following the entire length of the spinal cord At different levels it was reinforced by a variable number of anterior radicular arteries The anterior spinal rami from the vertebral arteries often varied in size In 2 cases one of a pair was absent In 4 other cases one of a pair was represented by 2 or 3 slender twigs that united with a large branch from the opposite side The point of fusion of the anterior spinal rami was most often found at the border between the medulla oblongata and the spinal cord Occasionally, however, the rami descended as far as the C2 or C3 segments before joining The size of the anterior spinal artery usually tapered gradually from the lower part of the cervical region down to the middle or lower thoracic region, but narrow parts of the artery also occurred in the upper thoracic region in some of the specimens At the point of junction with the great anterior radicular artery an enlargement was regularly observed It remained fairly constant in size down to the lower end of the sacral or coccygeal region Here the anterior spinal artery was suddenly reduced to a tiny vessel on to the conus and the filum terminale after giving off communicating branches (rami cruciantes) to the posterior spinal arteries (Fig 2) Most of the anterior radicular arteries terminated directly in the anterior spinal artery Not infrequently, however, both large and small-sized vessels branched at a variable distance from the midline into ascending and descending parts, both joining the anterior spinal artery

When anterior tributaries entered the same spinal cord segment from each side, the anterior spinal artery often displayed a rhomboidal shaped appearance, a feature frequently noted in the cervical region In some specimens the cervical part of the anterior spinal artery formed parallel duplicates over two or more segments (Fig 6)

The posterior spinal arteries came rostrally from the posterior rami of the vertebral arteries, occasionally from the inferior cerebellar artery They ran along the posterolateral surface of the cord near the entrance of the posterior nerve roots, at intervals



Fig 6 Transparent specimen photography Ventral view of the cervical cord Duplication (↔) of parts of the anterior spinal artery (asa) Tiny branches (→) distributed to the circumference of the cord Anterior root arteries (ara)

Fig 7 Transparent specimen photography Dorsal view of the cervical cord Arrangement of the paired posterior spinal arteries (psa) with winding course loop formations and large and small interconnections (→) The anterior spinal artery (asa) is discernible The anterior (ara) and posterior (pra) root arteries

receiving additional supply from the posterior radicular arteries At the lower end of the spinal cord the posterior spinal arteries communicated with the anterior spinal artery via rami cruciantes Circumferential branches were distributed to the posterior surface of the cord forming a more or less wide meshed network between the two arteries Other branches passed over the lateral surface and made tiny anastomotic connections with branches from the anterior spinal artery Now and then small nutrient branches were sent to the proximal part of the posterior rootlets and nerve roots most often in roots of the cauda equina

The posterior spinal arteries were usually distinct vessels but they were smaller than those of the anterior spinal arteries Short breaks or loop formations occurred on the postero-lateral surface of the cord preferentially in the cervical and upper thoracic part (Fig 7)

The arterial pial plexus

Circumferential branches from the anterior and the posterior spinal arteries formed the pial arterial network An additional supply was derived from the root arteries

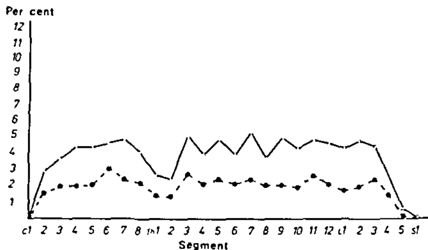


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Fig 8 Transparent specimen, photography Lateral view of the lumbar cord Occasional central arteries (ca) arising on a common stem from the anterior spinal artery (asa) Tiny connections between adjacent central arteries just behind the anterior spinal artery (→)

The penetrating branches from the posterior spinal arteries and the pial arterial plexus were concentrated mainly to the tip of the posterior grey horn and to the posterior midline The larger branches to the posterior horn usually pierced at acute angles from the posterior spinal arteries and extended more or less rostrally before terminating into a capillary plexus The posterior midline branches were relatively large and extended to the grey matter around the central canal of the cord They also supplied the main part of the posterior white matter The size and number of these branches gradually decreased from the lower thoracic region down to the lumbosacral cord

Short rami from the pial plexus penetrated the circumference of the spinal cord to supply parts of the white and grey matter Some of them extended into the center of the anterior grey matter Occasionally small rootlet arteries terminated into the ventral part of the anterior grey horn

Due to overlapping of the terminal arterioles a sharp borderline between the territories supplied from the central and the peripheral system was difficult to identify

terminating in the pia mater In all individuals the pial plexus appeared best developed on the posterior surface of the cord, not infrequently revealing comparatively large oblique or transverse branches between the two arteries (Figs 2, 7) On the ventral and lateral aspect of the circumference, the vessels were invariably small and formed a fine arteriolar network (Fig 6) Small branches from the pial arterial plexus penetrated into the substance of the spinal cord to supply the adjacent white and grey matter

The intrinsic arteries of the spinal cord

The nutrient vessels of the spinal cord parenchyma might be separated into a central and a peripheral arterial system The central system derived from the anterior spinal artery and the blood flow became centrifugal In the peripheral system the blood came from the posterior spinal arteries and the pial arterial plexus and the blood had a centripetal flow

The central arteries branched from the posterior surface of the anterior spinal artery and traversed the anterior median fissure to enter the base of the anterior grey horns The angle of departure from the anterior spinal artery varied, usually being obtuse in the cervical and thoracic regions, while almost at right angle in the lumbosacral cord Most often the arteries arose singly and supplied the right or the left side alternately, but occasionally 2 or 3 successive arteries ran on the same side Sometimes 2 central arteries branched from a short common stem and divided in the sagittal plane, one to each half of the spinal cord, most often in the lumbar and sacral region (Fig 8) but occasionally also at other levels

In some specimens small longitudinal anastomotic connections between two or more central arteries occurred close by their origin from the main trunk (Fig 8)

A contrast filling adequate for counting all the central arteries was obtained in eleven specimens The total number ranged from 184 to 228 in individual cases, the average was 210 The regional distribution was as follows the cervical region 38 to 53, average 47, thoracic region 76 to 94, average 86, lumbosacral region 60 to 84, average 76 The number of arteries to each segment ranged from 5 to 9, being more numerous in segments of the spinal cord enlargements Arteries to the lumbar cord were more closely spaced than those to the cervical cord Arteries to the thoracic cord were widest apart On reaching the anterior grey matter the arteries branched into short ascending and descending twigs in addition to horizontal branches usually traversing to the periphery of the grey matter before they terminated into capillaries The more widely spaced central arteries in the thoracic region tended to branch in the longitudinal direction while those in the cervical and lumbosacral region mainly branched in the horizontal plane, extending deeper into the cord The terminal branches overlapped both with those from above and from below and also with branches from the peripheral system The degree of overlapping apparently varied in different segments and regions of the cord, but seemed to be more marked in the cervical and lumbar enlargements than in other parts of the cord

made it easy to define their areas of supply The same observation was made by TURNBULL et coll

Previous authors have stressed the large range of variations in the width, number and location of the radicular arteries in individual cases JELLINGER made a numerical registration of personal findings and available data from the literature on the arrangement of anterior and posterior root arteries in altogether 800 human spinal cords He found that the number of anterior root arteries varied from 2 to 14, averaging 6 in individual cases In the cervical region 2 or 3 arteries followed the 5th or the 6th, less often the 7th nerve roots TURNBULL et coll in a report of 43 human cases found that in half of their material the arteries entered along the fifth and the fourth cervical nerve roots A similar scattered supply was observed in about three fifths of the present material, but the vessels were more equally distributed to the cervical segments from C4 to C7, i e the upper two thirds of the cervical enlargement About 30 per cent of the cervical arteries were arranged symmetrically on the right and the left side JELLINGER found the same in 16 per cent of his cases and in the table presented by TURNBULL et coll this occurred in 18 of 43 cases

A striking feature of the human spinal cord was the poor supply of ventral tributaries to the lower cervical and the upper thoracic segments, i e at the border of the vertebro subclavian and the aortic territories This region was by JELLINGER considered to be particularly vulnerable to impaired blood flow following a severe drop in the systemic blood pressure He suggested—quoting the works by SCHNEIDER (1953) and ZULCH (1954) on the hydrodynamic model of the 'last field' of an irrigation system—that due to the opposite directions of blood flow this area was particularly vulnerable to ischaemic injury JELLINGER found that the anatomic borderzone between the two sources *varied from C8 to Th3* in individual cases, in the average case C8–Th1 In the present material the border was most often found at Th1 Th2 *as deduced from* the arrangement of the ventral tributaries However, this anatomic border *does not necessarily* correspond to the functional one as pointed out previously (TVETEN), *although* JELLINGER claimed that most ischaemic lesions in the spinal cord are found between C8–Th1 and Th2.

From a clinical and pathologic analysis of spinal cord lesions associated with general vascular *disorders*, ZULCH and BARTSCH & HOPF (1963) concluded that the fourth thoracic *segment and* the thoracolumbar border of the cord is most often involved while LAZORTHES (1972) suggested that the mid thoracic (Th4 to Th7) region is the one most *vulnerable* because of the poor supply of collaterals in this region It is evident that the *problem* of specific vulnerable areas of the cord to ischaemia can only be solved by *employing* combined physiologic, angiographic and anatomic methods As far as known, no such combined experiments have been performed

The main number of anterior root arteries to the thoracolumbar cord entered from the left side especially at levels where the aorta is located distinctly to the left of the umn This feature has been commented upon by other authors



Fig 9 Transparent specimen photography Cross sections of a) the cervical b) the thoracic and c) the lumbar cord in a fullterm newborn Anterior (asa) and posterior (psa) spinal arteries central arteries (ca) pial vessels (pia) and vessels in ventral parts of the anterior grey horns (A)

Roughly estimated the central arteries supplied all the grey matter except the posterior half of the posterior grey horn while most of the white matter was supplied from the peripheral branches Occasionally, however, peripheral branches extended almost as far as the central grey matter, while twigs from the central arteries were found deep in the white matter

No anastomoses could be seen above the capillary level within the spinal cord

The capillaries within the spinal cord

The grey matter of the spinal cord was sharply outlined by its dense capillary network, which was best developed within the anterior and lateral grey horns The poorest supply to the grey matter appeared to be in the basal and middle part of the posterior grey horn, i e at the border between the central and peripheral systems (Fig 9) The white matter was poorly supplied and the capillaries formed wide meshes which extended longitudinally along the nerve fibers

Discussion

The present investigation of the vascular anatomy of the spinal cord lends support to the concept that the vascularity is fully developed before the seventh month of fetal life (His 1887, Torr 1957 a, b, Gillilan) Torr (1957 a) even stated that in fetuses of about 7 cm crown rump length, the basic adult appearances are easily recognizable Gillilan (1958) maintained that no changes of the vascularity of the spinal cord occur after the 6th month of intrauterine life Based upon these observations it seems justifiable to correlate the findings in the present material with those of other reports which mainly deal with the condition in adults

The techniques employed in the present work seemed well suited for demonstrating both large and small arteries Deficient filling of minute blood vessels, arterioles and capillaries, not infrequently observed in the present material may be due to the fact that discolouration of the cadaver was deliberately avoided However, the difference in filling of arteries in the central and peripheral systems occasionally found

taries Experiments indicate that in parts of the anterior spinal artery blood flows in opposite directions (TORR 1957 c, JELLINGER) In the present material narrow regions of the anterior spinal artery were frequently observed in the middle and lower part of the thoracic cord, most often immediately superior to its union with the great anterior radicular artery CORBIN and LAZORTHES et coll (1966 b) describe narrow parts and occasionally short breaks of the artery predominantly in the cervical region In agreement with other authors (NOESKE, ROMANES 1965, and TURNBULL et coll) the present findings demonstrate that a duplication of the anterior spinal artery reflecting its embryologic origin, is rather common in the cervical part of the artery

Some authors (ADAMKIEWICZ 1882, KADYI, METTLER 1948, NOESKE, ROLL, CLEMENS) describe three or four pairs of anastomotic channels on the postero-lateral and lateral surfaces of the spinal cord, naming the different chains according to their sites on the cord Since most of these vessels are distinct channels for a short distance only, a classification of these arteries would seem to be of no practical importance GILLILAN failed to demonstrate a single continuous vessel at the posterior or lateral aspect of the cord and she stated that 'the posterior spinal arteries are in fact two posterior plexiform channels running longitudinally on a line with the entrance of the rootlets of the posterior nerves'

The present material created no difficulties in demonstrating the posterior spinal arteries as distinct vessels or anastomotic channels, one on each side, usually extending the entire length of the spinal cord more or less closely applied to the posterior rootlets The results thus agreed with those of ROMANES, JELLINGER, TURNBULL et coll , HASSLER, PISCOL and others In some specimens, however, small splits or breaks of the artery were noted, most often in the cervical region, while loop formations or tortuosity of the vessels were characteristic findings in the thoracic and, to some extent, in the lumbar regions TURNBULL et coll observed tortuosity of the vessels in the posterior pial plexus and the root arteries of the cervical region in old people and appeared to regard this as an old age phenomenon

In the present material the posterior spinal arteries communicated by way of relatively large branches crossing the posterior surface of the cord These anastomoses were mainly concentrated at the spinal cord enlargements These findings agreed with those of ROMANES TUREEN (1938) on the other hand, stated that the surface connections were best developed in the lower lumbosacral region

The only conspicuous anastomoses between the posterior and the anterior spinal arteries were found at the level of the conus medullaris This anastomotic connection had the form of an arterial ring surrounding the conus by way of rami cruciantes Not infrequently, however, one of the two rami was absent LAZORTHES et coll (1966 a) stated that the anastomotic ring around the conus medullaris was invariably reinforced by more sacral root arteries This was a rather infrequent finding in the present series as most of the sacral root arteries branched off on the roots

The pial arteries on the lateral and ventral surfaces of the cord were very small

(LAZORTHES et coll 1958, HASSLER, PISCOL) *The same applied to the great anterior* radicular artery which in general is considered to be the sole source of supply to the lower thoracic and lumbosacral cord In about one third of the present cases additional small arteries—one or rarely two—were seen below the entrance of the great ventral feeder JELLINGER described accessory lumbar arteries in about one half and one third of the cases in which the great anterior root artery entered at a thoracic or a lumbar level, respectively He believed that this explains segmental variations of vascular lesions in the lower part of the spinal cord PISCOL also observed the additional arterial supply to the lumbosacral cord

The fact that the level of entry of the great anterior root artery (the artery of Adamkiewicz) varies considerably in individual cases, was confirmed in the present material JELLINGER described the artery between Th6 and L5, in about two thirds *of the cases arising from the lower thoracic region, Th9 to Th12 Similarly*, LAZORTHES et coll (1958), CORBIN as well as DJINDJIAN (1969) observed this artery in the low thoracic region in 75 to 80 per cent of their cases SUH & ALEXANDER (1939) and GILLILAN, however, claimed that it usually enters with the first or the second lumbar nerve roots

LAZORTHES et coll (1962, 1966 a) and HETZEL (1965) found that the artery of Adamkiewicz gave rise both to a ventral and a dorsal feeder of the cord LAZORTHES et coll *(1962, 1966 a) appear to hold the opinion* that separately running posterior root arteries do not exist This view is not shared by other authors such as KADYI GILLILAN, JELLINGER, TURNBULL et coll and PISCOL In fact most authors maintain that the spinal arteries rarely bifurcate into a significant ventral and dorsal feeder However, JELLINGER stated that the great anterior radicular artery is associated with *a dorsal spinal cord feeder in about 50 per cent of his cases* The same observation was made in about one third of the present material, the point of branching from the common stem being outside the dura mater, as previously pointed out by TURNBULL et coll

As to the posterior root arteries the present findings tally fairly well *with those observed in a larger series of humans (for ref see* JELLINGER) *They were more evenly* distributed than the anterior ones and not infrequently entered the spinal cord segment from both sides The existence of a great posterior root artery similar to that of the anterior root, has in the past been a subject of dispute (see JELLINGER) Results from the present series, in accordance with GILLILAN, indicate that not infrequently one or two posterior root arteries in the lumbar region were *slightly more prominent* than others in the series, but none of these was ever so impressive as its anterior counterpart

The observation of GILLILAN that the feeders to the cord do not contribute to the supply of the roots themselves, is in accordance with the present observations

Previous descriptions of the anterior spinal artery differ mainly *in viewing* the artery as an anastomotic chain between the anterior root arteries or as a continuous vessel Narrow parts of the artery are frequently described between adjacent tribu

picture of the capillary network is probably never achieved by post-mortem injection (KORMANO 1970) Nevertheless, in the present material the constant occurrence of a relatively poor filling of capillaries in the basal part of the posterior horn is evident, corresponding fairly well to the border between the central and the peripheral systems of arterial supply This zone is by several authors (among others ZULCH and JELLINGER) considered to be particularly vulnerable to a general disturbance in the spinal cord circulation

SUMMARY

The arterial supply of the human spinal cord was investigated in detail using microangiography and binocular microscopy after the specimens had been made transparent (1) The arterial tributaries to the spinal cord were found to come from the anterior radicular arteries in a total number varying from 3 to 15, and from posterior radicular arteries numbering 14 to 25 The location of the great anterior radicular artery varied from Th8 to L3 This artery was most often the only ventral feeder to the lower cord (2) The surface arteries of the spinal cord were mainly derived from the posterior longitudinal arteries with only tiny anastomoses from the anterior spinal artery The pial arterial plexus was best developed over the posterior surface of the cord, particularly at levels of the enlargements (3) The *intramedullary* central part is supplied by the anterior spinal artery and a peripheral part mainly from the posterior longitudinal arteries Anastomotic connections between the two systems or between individual arteries within the two systems could not be observed

ZUSAMMENFASSUNG

Die arterielle Versorgung des Ruckenmarkes wurde im Einzelnen unter Verwendung von Mikroangiographie und binokularer Mikroskopie, nachdem die Praparate transparent gemacht worden *waren* untersucht (1) Die arteriellen Zuflusse des Ruckenmarkes kommen von den vorderen Aa radiculares in einer Gesamtzahl [illegible]

[illegible] gung des unteren Ruckenmarkes (2) Die oberflachigen Arterien des Ruckenmarkes *kommen hauptsächlich* von den hinteren längslaufenden Arterien mit lediglich feinen Anastomosen von der vorderen A spinalis Der arterielle Plexus in der Pia mater war uber der hinteren *Flache des* [illegible]

[illegible] dieser beiden Systeme konnten nicht beobachtet werden

RÉSUMÉ

L irrigation artérielle de la moelle epinière de l homme a été etudiée en detail par microangiographie et microscopie binoculaire après diaphanisation des pieces (1) Les artères qui vont à la moelle proviennent des *artères radiculaires* anterieures dont le nombre total

and in agreement with TURNBULL et coll these vessels were considered to be usually functionally insufficient as anastomotic pathways between the anterior and the posterior spinal arteries Clinical and pathologic observations of posterior spinal cord infarction as opposed to anterior spinal cord infarction are in line with this view

The main supply of the spinal cord substance is transmitted by about 200 central arteries The figures found in the literature vary from 180 (KADYI), — 200 (JELLINGER) to 250–300 (ADAMKIEWICZ 1881, SUH & ALEXANDER, GILLILAN) In accordance with TUREEN but contrary to JELLINGER the total number of arteries of the thoracic region in the present material was found to be somewhat higher than that of the cervical and lumbosacral regions although the arteries of the thoracic region were more widely spaced The number of arteries entering the spinal cord segment in the present material tallies well with the average number (6 or 7) observed by CLEMENS while HERREN & ALEXANDER (1939) found that each segment of the cord usually received 4 central arteries only

The postulation of FAZIO (1938) and FAZIO & AGNOLI that branches from the central arteries form longitudinal anastomotic channels in the depth of the anterior median fissure and also within the cord, i e ventral to the central canal, was not confirmed in the present series, where the communications occasionally observed were short, inconstant connections between a few central arteries in the ventral part of the anterior median fissure Transverse connections between the terminal arterioles as also described by these authors could not be confirmed in the present material

Whether occasional central arteries may bifurcate to both sides i e arise on a common stem from the anterior spinal artery, has been a matter of dispute TORR (1957 c) and GILLILAN failed to demonstrate this feature in human infants In adults however, it has been repeatedly observed (ADAMKIEWICZ 1882, JELLINGER, TURNBULL et coll , HASSLER) Employing microangiography, HASSLER observed frequent bifurcations of the central arteries in different regions of the spinal cord, and in accordance with TURNBULL et coll he emphasized the importance of views with the specimen in the lateral position since division of the vessels always occurs in the sagittal plane The findings in human infants from the present series are in good conformity with their observations

Most authors consider the central and the peripheral systems of arterial spinal cord supply to be separate since no anastomoses between the intramedullary arteries have been demonstrated The border between the two systems was often ill defined due to overlapping of their terminal branches The amount and degree of overlapping of branches varied somewhat from one level to another, but was in accordance with the statement of HASSLER that 'the same tracts and parts of the grey matter were supplied by the same arterial system in the whole cord

In specimens with well filled vessels the grey matter of the spinal cord was clearly outlined by its extensive capillary network, contrasting the scanty supply to the white matter TURNBULL et coll suggest a dense concentration of capillaries around the anterior horn cells and at the periphery of the great matter However, a complete

picture of the capillary network is probably never achieved by post mortem injection (KORMANO 1970). Nevertheless, in the present material the constant occurrence of a relatively poor filling of capillaries in the basal part of the posterior horn is evident, corresponding fairly well to the border between the central and the peripheral systems of arterial supply. This zone is by several authors (among others ZULCH and JELLINGER) considered to be particularly vulnerable to a general disturbance in the spinal cord circulation.

SUMMARY

The arterial supply of the human spinal cord was investigated in detail using microangiography and binocular microscopy after the specimens had been made transparent. (1) The arterial tributaries to the spinal cord were found to come from the anterior radicular arteries in a total number varying from 3 to 15 and from posterior radicular arteries numbering 14 to 25. The location of the great anterior radicular artery varied from Th8 to L3. This artery was most often the only ventral feeder to the lower cord. (2) The surface arteries of the spinal cord were mainly derived from the posterior longitudinal arteries with only tiny anastomoses from the anterior spinal artery. The pial arterial plexus was best developed over the posterior surface of the cord, particularly at levels of the enlargements. (3) The intramedullary central part is supplied by the anterior spinal artery and a peripheral part mainly from the posterior longitudinal arteries. Anastomotic connections between the two systems or between individual arteries within the two systems could not be observed.

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RESUMÉ

L'irrigation artérielle de la moelle epinière de l'homme a été étudiée en détail par microangiographie et microscopie binoculaire après diaphanisation des pièces. (1) Les artères qui vont à la moelle proviennent des artères radiculaires antérieures dont le nombre total

varie de 3 à 15 et des artères radiculaires postérieures au nombre de 14 à 25 La situation de la grande artère radiculaire antérieure varie de D8 à L3 Cette artère est le plus souvent le seul vaisseau nourricier antérieur de la partie inférieure de la moelle (2) Les artères superficielles de la moelle proviennent principalement des artères longitudinales postérieures et reçoivent seulement de fines anastomoses de l'artère spinale antérieure Le plexus artériel pial est plus développé sur la face postérieure de la moelle, particulièrement au niveau des renflements (3) La région centrale intramédullaire est irriguée par l'artère spinale antérieure et la partie périphérique principalement à partir des artères longitudinales postérieures. L'auteur n'a pas observé d'anastomose entre ces deux systèmes ou entre des artères à l'intérieur de chacun de ces deux systèmes

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COMPLICATIONS OF ORBITAL AND SKULL BASE PHLEBOGRAPHY

GUDRUN BRISMAR, J BRISMAR and S CRONQVIST

Two techniques, differing in principle, can be used to demonstrate the intraorbital veins and the veins of the skull base the anterior approach via the facial veins and the posterior approach via the internal jugular veins

For the anterior approach different facial veins have been used DEJEAN & BOUDET (1951) suggested, when introducing the technique of orbital phlebography, that the angular vein should be exposed surgically and cannulated, while YASARGIL (1957) demonstrated that this vein could be punctured percutaneously BROVKINA (1964) advocated catheterization of the anterior facial vein The frontal vein puncture technique was introduced by YASARGIL and VRITSIOS (1961) and is now commonly used Scalp vein needles were used previously for the puncture but during the last years have been replaced by teflon cannulas with a metal mandrin (VIGNAUD & CLAY 1969 BRISMAR 1974) The use of these cannulas permits a more rapid injection of contrast medium—the technique now used usually involves the injection of 10 ml of medium in 1 to 2 seconds

For the posterior approach, the inferior petrosal sinus is catheterized after percutaneous puncture of the internal jugular vein (HANAFEE et coll 1965) The inferior petrosal sinus may also be catheterized after percutaneous puncture of the femoral vein (TAKAHASHI & TANAKA (1971)

SHIU et coll (1968), when presenting the results of the first 100 phlebographies via

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the inferior petrosal sinus, described three complications encountered In association with the examination, a lateral medullary syndrome developed in one case, completely disappearing within 24 hours The complication was interpreted as having been caused by the rupture of pontine veins In two additional cases, contrast medium extravasated from the inferior petrosal sinus but without symptoms or signs Although several thousand orbital phlebographies have been performed, only one paper has so far presented complications, SAFER & GUIBOR (1975) in a series of 52 orbital phlebographies encountered three complications In one patient, transient unilateral blindness followed the phlebographic procedure and was considered as being due to dilated veins of the optic disc occluding the central retinal artery In one case, one week after phlebography, a fresh intramacular hemorrhage was found resulting in a transient decrease in vision In the third case a massive retrobulbar bleeding developed at phlebography and was followed by permanent loss of vision

The aim of the present report is to present two additional cases of complications, one in association with orbital phlebography and one in association with phlebography via the inferior petrosal sinus, and to discuss the risks associated with the procedures

Case reports

Case 1 A 75 year old, previously healthy woman was referred for neuroradiologic examination under the diagnosis intracranial aneurysm or right-sided intraorbital space occupying lesion She had for two months noticed reddening of the right eye followed by right-sided proptosis and an increasing bruit in the right ear Vision was normal, intraocular pressure moderately increased on the right side A homonymous right-sided superior quadrantic anopsia was also found which remained unchanged during the entire observation time and was considered as an accidental finding

Orbital phlebography demonstrated partial thrombosis of the right superior ophthalmic vein and deformation of the right cavernous sinus Furthermore, the contrast medium was rapidly washed away from the right superior ophthalmic vein, suggesting an arteriovenous fistula

Phlebography of the right inferior petrosal sinus was performed to evaluate the ve[illegible] of the skull base and d[illegible]

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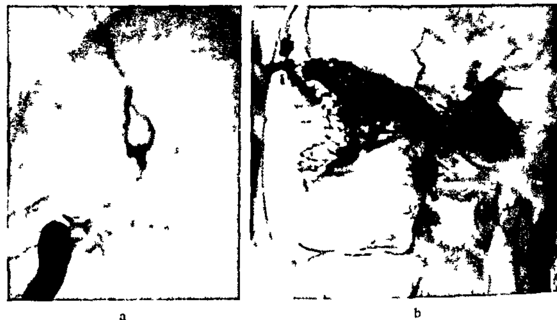


Fig 1 Case I Inferior petrosal sinus phlebography a) Axial view Extensive irregular post thrombotic abnormalities b) Lateral view Reflux of contrast medium into the carotid siphon (→) and into external carotid artery branches (↔)

resolved leaving some synechies During the following months the vision in the right eye improved successively but 6 months after the initial examination it was still considerably decreased The proptosis has subsided successively and returned to the same degree as before examination

Case 2 A 48 year old woman with arterial hypertension had three years earlier been subjected to a thorough clinical and neuroradiologic examination She had presented with a one year history of headache and periods of diplopia The clinical examination at that time disclosed oculomotor paresis papilledema an enlarged blind spot and a progressive reduction of vision in the left eye Neuroradiologic examination at that time demonstrated only an occlusion of the left superior ophthalmic vein at the superior orbital fissure and a slight reduction in the diameter of the carotid siphon on the left side The patient was treated with steroids and all symptoms and signs completely disappeared Except for shorter periods with left sided papilledema and decreased vision the patient was thereafter almost completely free of symptoms Two years later the previous symptoms recurred and in addition the patient noticed paresthesia on the left upper lip and cheek Complete neuroradiologic examination at this time demonstrated ventricular dilatation and severe abnormalities in the cerebral arteries with irregular reduction of lumen and multiple occlusions with collateral circulation Orbital phlebography (Fig 2 a) demonstrated bilateral occlusion of the superio[illegible]

series demonstrated an extravasation of contrast medium outlining the globe [illegible] sequelae of the extravasation were found at subsequent ophthalmologic examinations

One year later the patient died after having developed a progressive dementia and mental deterioration in addition to increasing neurologic signs



a



b

Fig. 2 Case 2 Orbital phlebography a) A p view Bilateral occlusion of the superior ophthalmic vein b) A p view from later series Rupture of intraorbital vein (⟶) Extravasated contrast medium outlining the globe (⟶)

Discussion

The basal sinuses of the skull are, because of the different structure of the wall, much less distensible than normal veins For this reason it is easy to understand that if during inferior petrosal sinus phlebography the catheter obstructs the lumen of the sinus, an injection of contrast medium will cause a considerable increase in intravasal



Fig 1 Case 1 Inferior petrosal sinus phlebography a) Axial view Extensive irregular post thrombotic abnormalities b) Lateral view Reflux of contrast medium into the carotid siphon (→) and into external carotid artery branches (↔)

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One year later the patient died after having developed a progressive dementia and mental deterioration in addition to increasing neurologic signs

mimic intraorbital tumours (BRISMAR & BRISMAR) the implication of this statement would be that orbital phlebography should never be performed in the examination of unilateral exophthalmos Beyond doubt, the increased intraorbital venous pressure carries a potential risk of causing rupture to a previously injured vein—this risk, however, in the light of world-wide experiences from several thousand phlebographies, seems to be minimal if compression of the jugular veins is avoided

SUMMARY

Two complications, one in association with frontal vein phlebography and one in association with inferior petrosal sinus phlebography, are presented Possible mechanisms for complications are discussed It is concluded that a significant risk exists in association with inferior petrosal sinus phlebography, particularly in association with vascular disorders of the skull base, while the risk in association with orbital phlebography after frontal vein puncture is minimal if compression of the jugular veins is omitted

ZUSAMMENFASSUNG

Zwei Komplikationen, die eine im Zusammenhang mit Phlebographie einer V frontalis, die andere im Zusammenhang mit Phlebographie des Sinus petrosus inferior, werden beschrieben Die moglichen Mechanismen fur diese Komplikationen werden diskutiert Die Verfasser schliessen daraus, dass im Zusammenhang mit der Phlebographie des Sinus petrosus inferior, besonders im Zusammenhang mit vaskularen Veränderungen der Schädelbasis, [illegible] d das Risiko im Zusammenhang mit der Phlebo- [illegible] frontalis minimal ist, falls eine Kompression der

RÉSUMÉ

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pressure The increase in pressure will, of course, be still higher if the venous bed is reduced by extensive thromboses as in case 1 Whether the widening of the fistula in this case was due to dislodgement of thrombi partially occluding the fistula or to vascular rupture cannot be stated with certainty

The examination procedure also carries the risk that the catheter tip may injure the wall of the sinus, thereby causing a rupture at the injection site This may be the explanation of the two complications described by HANAFEE et coll, where contrast medium extravasated from the inferior petrosal sinus

The situation is quite different in orbital phlebography via a frontal vein The frontal veins are highly distensible and a rich anastomotic net of veins normally exists in the forehead If the intravenous pressure is too high during injection, normally some of these small veins rupture, thereby reducing the risk of too high pressure in *the intraorbital veins Furthermore, though a tourniquet is placed round the forehead* above the injection site in order to compress the frontal veins, this compression is never absolute Thus alternative drainage routes exist In spite of these facts, however, the intraorbital venous pressure may rise high enough to cause a reversion of flow in the small external carotid branches supplying a carotid cavernous fistula (BRISMAR & BRISMAR 1976) The intraorbital venous rupture in case 2 may be explained as a consequence of the combination of bilateral superior ophthalmic vein occlusion with a disorder of the vascular walls

The collection of 3 cases of complications in a total material of 52 phlebographies (SAFER & GUIBOR) is most remarkable As no complications had ever been reported previously, in spite of the fact that several thousand phlebographies had already been performed, it is tempting to search for the explanation in differences in technique used In order to distend the frontal veins for puncture, SAFER & GUIBOR placed a *blood pressure cuff 7 6 cm wide around the neck of the patient* and inflated it to 40 to 50 mm Hg As appears from their report, this compression was then maintained during the phlebography This procedure of necessity produces a prolonged increase in intracranial as well as intraorbital venous pressure—a pressure increase that may be hazardous in several disorders However, this compression of the jugular veins is not necessary for the puncture, which can be performed with an even higher rate of success during compression of the forehead veins by means of a tourniquet placed supraorbitally As the aim of compression during phlebography is to obstruct alternative *facial draining routes in order to direct the contrast medium from the* injection site via the orbital veins to the basal sinuses of the skull and further down to the internal jugular veins, it seems illogical to occlude these latter veins

In their report, SAFER & GUIBOR suggested several contraindications for orbital phlebographies diabetic, arteriosclerotic or hypertensive retinopathy, central retinal artery or vein occlusion, arteriovenous communications, intraorbital or intrabulbar angiomas, hemangiomas and lymphangiomas, as well as blood dyscrasias As intraorbital angiomas and lymphangiomas are common types of intraorbital tumours, and *since* arteriovenous communications such as carotid cavernous fistulas, often

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ANGIOGRAPHIC DIAGNOSIS OF TELEANGIECTASES WITH CAVERNOUS ANGIOMA OF THE POSTERIOR FOSSA

Report of two cases

C DIAMOND A TORVIK and P AMUNDSEN

The vascular malformations of the nervous system may be divided into five types (1) arteriovenous malformations, (2) venous angiomas, (3) varices, (4) teleangiectases, and (5) cavernous angiomas (MCCORMICK 1966, RUSSEL & RUBINSTEIN 1971, JELLINGER 1975) On angiography the arteriovenous malformations are usually evident whereas the other types frequently are not possible to demonstrate (ROBERSON et coll 1974)

The arteriovenous malformation is composed of a tangle of thick-walled arteries and veins, usually with wide feeding arteries and draining veins, and frequently gives rise to hemorrhages The venous angioma is composed of veins only, but otherwise resembles an arteriovenous malformation It is most frequent in the spinal canal Varices consist of one single or a few dilated veins Occasionally they give rise to massive hemorrhages *Teleangiectases* are groups of vessels with thin walls resembling capillaries The individual vessels are completely surrounded by more or less normal parenchyma They rarely give rise to hemorrhages The cavernous angioma is composed of multiple closely packed vascular spaces forming honeycomb-like structures without intervening parenchyma The vessel walls are thin without smooth muscle or elastic fibers, hemorrhages are common

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Fig 1 Case 1 a) Encephalography Pontine expanding process b) Vertebral angiography, late venous phase Multiple enlarged vessels in both cerebellar hemispheres (→), mostly on the left side The vessels probably drain into the left petrosal vein via an enlarged vein of the lateral recess (↦)

In a few cases of cavernous angiomas enlarged draining veins have been demonstrated on angiography (BOGREN et coll 1970, LILIEQUIST 1975) and occasionally an accumulation of contrast medium has been observed both in cavernous angiomas and teleangiectases (POSER & TAVERAS 1957, LILIEQUIST) ROBERSON et coll described the angiographic features in a case of teleangiectases of the cerebellum and cavernous angioma of the pons The appearances of the vessels were suggested to be characteristic In the venous phase of vertebral angiography a cluster of distended vessels were demonstrated, radiating towards the midline from the center of each cerebellar hemisphere and emptying into an enlarged precentral cerebellar vein It was suggested that the combination of characteristic vessels solely in the venous phase, the presence of a mass, and a progressive neurologic syndrome should indicate teleangiectases with hemorrhage from a cavernous angioma, although distinction from other 'cryptic' malformations and vascular tumours may not be possible in some instances The present report concerns two cases with clinical, radiologic and pathologic findings similar to those reported by ROBERSON et coll

Case reports

Case 1 A 48-year-old man was admitted because of progressive diplopia of one year's duration, paresthesia in the right half of the body and unsteadiness of the right arm and leg He had nystagmus and paresis of the left abducens nerve The spinal fluid was normal Bilateral carotid and vertebral angiographies were considered normal at the time of examination but in retrospect a pontine mass was suggested

On readmission one year later the patient had a gaze paresis to the left, a slight left facial paresis and a slight right hemiparesis The spinal fluid was normal Angiography and encephalography demonstrated a pontine mass (Fig 1 a) which was considered to be a glioma A course of radiation therapy (3 800 R) was administered, possibly followed by slight improvement

The patient was again readmitted 12 months later with progressive cranial nerve signs, a slight hemiparesis and a marked cerebellar ataxia The spinal fluid was still normal

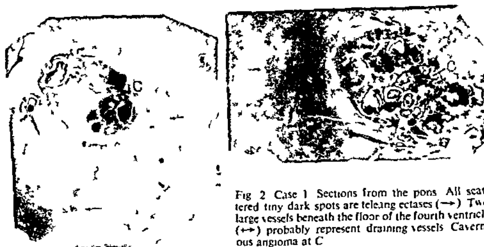


Fig 2 Case 1 Sections from the pons All scattered tiny dark spots are teleangiectases (→) Two large vessels beneath the floor of the fourth ventricle (↔) probably represent draining vessels Cavernous angioma at C

Repeat encephalography and angiography did not disclose any increase in the size of the pontine mass In the late venous phase a cluster of veins were seen in the posterior fossa radiating from the hemispheres of the cerebellum towards the midline These vessels were somewhat larger on the left than on the right side and they appeared to drain into the left petrosal vein (Fig 1 b)

Five months later cerebral angiography and encephalography findings were essentially unchanged, with no signs of hydrocephalus At craniotomy ectatic veins were seen protruding into the floor of the fourth ventricle The patient expired on the third postoperative day approximately 3 years after onset of symptoms the cause of death was bronchopneumonia

Gross examination of the brain The weight of the brain was 1 440 g The dura dural sinuses and the arteries on the base of the brain were normal The left half of the pons was somewhat enlarged On cross section a 2 cm wide sharply circumscribed hemorrhagic discoloration of the left half of the pontine tegmentum was observed extending rostrocaudally throughout the entire pons (Fig 2) Otherwise the brain was grossly normal No abnormalities were recorded in the cerebellum

Microscopy revealed numerous thin walled vessels with diameters varying from 50 to 500 μ throughout the entire pons (Figs 2 3 a) The vessel walls were composed of regular endothelium and a barely discernible layer of collagenous tissue Generally these diffusely distributed vessels had the characteristics of teleangiectases The parenchyma between the vessels was largely normal but old microinfarcts were found scattered throughout the pons Beneath the floor of the fourth ventricle two large veins were located each with a diameter of about 2 mm these were probably enlarged draining veins (BLACKWOOD 1941)

The center of the grossly discolored *area in the left* pontine tegmentum was the site of a honeycomb-like cluster of irregularly shaped vascular channels without intervening parenchyma (Figs 2 3 b) The vessels had a diameter of 1 to 2 mm with walls composed of an uneven layer of connective tissue without smooth muscle or elastic compounds Recent and old thrombi occluded some of the lumina and hemorrhages and infarcts of varying age were seen in the surrounding pontine tissue There was a gradual transition between this dense cluster of vessels which had the appearance of a cavernous angioma and the diffusely distributed thin walled teleangiectases in the remainder of the pons Most of the tissue destruction in the pons was caused by hemorrhages and thromboses within the angioma and not by hemorrhages adjacent to the teleangiectases The angiographic appearances

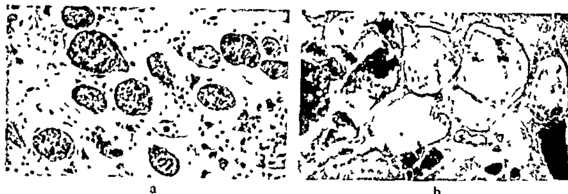


Fig 3 Case I Sections from pons a) Teleangiectases × 160 b) Cavernous hemangioma Hematoxylin eosin 60



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(similar to those of Case 2) indicate that teleangiectases were present also in the cerebellar white matter but no sections were taken of the cerebellum for microscopy

Case 2 A 38-year-old woman presented with fleeting paresthesias of the left half of the body and stiffness of the right side of the face for some months followed by headache dizziness, nausea, and vomiting of a few weeks' duration Neurologic examination revealed hypoesthesia of the left half of the body and the right side of the face, gaze paralysis to the right, mild dysarthria and extensor plantar response on the left side The spinal fluid was normal

Bilateral carotid and vertebral angiography was initially considered as normal Encephalography demonstrated an expanding pontine mass which was thought to represent a tumour (Fig 4 a) Following two courses of radiation therapy and steroid treatment with a transitory improvement, the patient again gradually deteriorated and died 3 months after admission, the cause of death was bronchopenumonia

At a review of the vertebral angiography a bilateral cluster of vessels was found in the venous phase, converging towards the midline from each cerebellar hemisphere and apparently draining via the brachial veins into the precentral cerebellar vein (Fig 4 b)

Gross examination of the brain The brain weight was 1 410 g The dura and dural sinuses and the arteries on the base of the brain were normal The pons was markedly enlarged by a



Fig. 5 Case 2 Midsagittal section Pontine hematoma Large vein in cerebellar white matter (→)

hematoma destroying most of the pontine tissue with elevation of the floor of the fourth ventricle posteriorly (Fig 5) The fourth ventricle was nearly obliterated but the lateral ventricles were only slightly dilated The vessels in the white matter of the cerebellum appeared unusually wide Otherwise, the brain was grossly normal

Microscopy The central part of the pons was completely destroyed by the large hemorrhage In most parts the hematoma was old and surrounded by a thin capsule of connective tissue Outside the capsule a gliotic zone was present with numerous macrophages containing hemosiderin and lipids No definitely abnormal vessels were seen within the hematoma or in the pontine tissue surrounding it

The cerebellar white matter contained numerous thin-walled vessels which appeared to radiate outwards from the region of the fourth ventricle (Fig 6) The abnormal vessels extended into the white matter of nearly all cerebellar folia The diameter varied from 3 mm centrally to 1 mm in the periphery The vessels partly occurred as single elements, partly in small groups They were always completely surrounded by cerebellar parenchyma Occasional hemosiderin macrophages were present along the vessel walls, indicating a slight leakage of blood Generally, these abnormal vessels had the characteristics of teleangiectases, although the distinction between teleangiectases and a venous angioma in this case may be arbitrary

The exact origin of the pontine hemorrhage was not demonstrated in this case However, in view of the vascular malformations present in the cerebellum it seems likely that the hemorrhage was caused by a pontine vascular malformation which had been destroyed by the hematoma

Discussion

The clinical, radiographic, and pathologic findings in these two cases are similar to those described by ROBERSON et coll It is particularly relevant that a late filling of abnormal radiating veins in the cerebellum may indicate the presence of a pontine vascular malformation which is otherwise not angiographically visible The patients had slowly progressing neurologic symptoms without ictal episodes, thus simulating pontine neoplasms, and the demonstration of a pontine mass by encephalography could support this diagnosis

Correlation between angiography and pathology The distinction between the various subtypes of vascular malformation is somewhat arbitrary and various combinations may occur (RUSSEL & RUBINSTEIN) The present Case 1 and the case published by ROBERSON et coll are examples of combined teleangiectases and cavernous angioma The characteristic angiographic appearances in the venous phase probably were

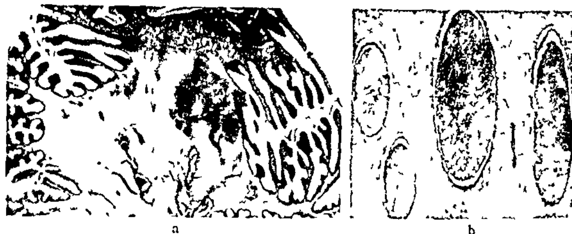


Fig 6 Case 2 Cerebellum a) Numerous teleangiectases in white matter (→) 1 5 b) Teleangiectases at higher magnification Hematoxylin-eosin 70

caused by the teleangiectases and their enlarged draining veins in the cerebellum and not by the symptomatic pontine malformation In Case 2 the teleangiectases in the cerebellum were evident while the exact nature of the pontine vascular malformation could not be established It should be emphasized that the unique angiographic appearance may be expected only when the pontine malformation is associated with extensive cerebellar teleangiectases

Generally, cavernous angiomas do not exhibit an accumulation of contrast medium on angiography (JONUTIS et coll 1971, ROBERSON et coll), this also applied to Case 1 Since cavernomas are shunted on the venous side of the circulation and contain a large reservoir of slowly flowing blood, the absence of accumulation of contrast medium may be due to dilution of the medium in this reservoir On the other hand, the draining veins, which receive their blood both from the normal tissue and the malformation, would contain a higher concentration of the contrast medium and could conceivably be demonstrated

Clinical correlations The symptoms and signs of vascular malformations are caused by tissue destruction due to hemorrhages and infarcts, and by compression from expanding vessels A steal mechanism may also be involved, but probably only in arteriovenous malformations On this background, it is remarkable that both the present cases had insidious onset and a gradually progressive clinical course without ictal episodes A similar non-ictal and slowly progressive development has apparently been found in many pontine vascular malformations (ZELLER & CHUTORIAN 1972, ROBERSON et coll , WALTER 1975) Partly the progression may be explained by repeated hemorrhages and progressing infarction due to thrombosis However, the complete absence of ictal episodes remains puzzling It is also remarkable that the spinal fluid was normal throughout the course in both cases

Although the clinical and radiologic distinction from tumours may be uncertain, it is important to remember that the combination of a progressive pontine syndrome,

a pontine mass demonstrated on encephalography, and a characteristic angiographic venous appearance of the cerebellum may be caused by a bleeding vascular malformation in the pons

SUMMARY

Two cases of pontine vascular malformation with a characteristic venous angiographic appearance are reported Both patients had a slowly progressive clinical course, normal spinal fluid, and evidence of a pontine mass In the late venous phase, large abnormal vessels were seen to converge towards the midline from each cerebellar hemisphere The abnormal vessels were microscopically identified as teleangiectases in one of the cases Both cases had pontine hematomas originating from a cavernous angioma in one of them, in the other the exact origin of the bleeding could not be determined It is concluded that in cases with a progressive pontine syndrome the characteristic appearance of the venous phase of angiography may indicate a bleeding pontine vascular malformation

ZUSAMMENFASSUNG

Zwei Falle von Missbildung der Gefasse der Pons mit einem charakteristischen venosen angiographischen Bild werden beschrieben Beide Patienten hatten einen langsam fortschreitenden klinischen Verlauf, eine normale Spinalflussigkeit und eine Verdickung der Pons In der späten ...
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RESUMÉ

Presentation de deux cas de malformation vasc ... ant un aspect
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OBJECTIVE SYMMETRY DETECTOR METHOD FOR GAMMAENCEPHALOGRAPHY

VI Comparison with subjective evaluation of brain scintigraphy

MAGNUS LIND

The physical characteristics and normal range of the objective symmetry detector method for gammaencephalography as well as a method for the objective interpretation of results have been described previously, the $^{99}Tc^{m}O_4$ distribution in the skull by this method was objectively classified as abnormal in about 95 per cent of the examined brain tumour cases (LARSSON et coll 1975, LIND et coll 1975, LIND & LARSSON 1975, LIND 1975)

The diagnostic value of gamma camera examination of the skull, brain scintigraphy or gammaencephalography according to PLANIOL (1966) and MUNDINGER & ASAI (1967) has been assessed by several authors (PAOLETTI et coll 1969, TAKEDA 1970, BURROWS 1972, SAUER 1972, YOUNG & ROCKETT 1972) However, different principles for the selection of patients have been used and the number of false positive cases is often not reported in detail Hence, it is difficult to evaluate the results reported, and it is not possible to decide which method offers the highest diagnostic accuracy, i e is most efficient in separating brain tumour cases from normal cases

The objective symmetry detector method was developed in order to obtain an uncomplicated and inexpensive method for clinical routine screening of patients with

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Table 1

Classification scheme used both for the subjective classification of brain scintigrams and the objective classification made by the symmetry detector method

Class	Denomination	SD_{max}	Intended level of probability
I	Definitely normal	-3 0	1 00-0 95
II	Probably normal	3 0-3 5	0 95-0 50
III	Probably abnormal	3 5-4 0	0 50-0 05
IV	*Definitely abnormal*	4 0-∞	0 05-0 00

possible brain tumour The subjective interpretation of brain scintigrams has been shown to constitute a source of considerable variation, which can be avoided by using the objective symmetry detector method (LIND 1976) The purpose of the present communication is to compare the results of conventional routine brain scintigraphy with those of the objective symmetry detector method

Material and Methods

The material consisted of 103 patients, examined and grouped A–D according to their diagnoses as described previously (LIND 1976)

A 29 cases, no neurologic symptoms

B 48 patients, epileptic attacks or headache, no further sign of organic brain lesion

C 18 patients, intracranial neoplasm

D 8 patients, diagnoses uncertain

The objective symmetry detector method has been described in detail elsewhere (LARSSON et coll, LIND et coll) The nuclide distribution was determined from measurements over 24 subregions of the skull (see Fig 1 in LARSSON et coll and Fig 2 in LIND et coll) Nine evaluation parameters were calculated for each subregion, altogether 208 (LIND et coll)

The maximum deviation from the normal mean value in any of these 208 evaluation parameters was expressed as number of standard deviations (SD_{max}) and used as a criterion (LIND et coll, LIND & LARSSON)

Brain scintigraphy was performed with a Picker Magna Scanner III (LIND 1976)

The scintigrams from patients in groups B–D were codified, the original identifications were covered and they were all randomized in one group, altogether 74 examinations The scintigraphic findings were analysed and classified by 10 radiologists without internal communication or any clue to the identity of the patients The interpreters were requested to estimate the probability (p) of the findings to be normal or abnormal, and then to classify them as demonstrated in Table 1 The boundaries between the four classes were defined by p = 0 95, 0 50 and 0 05, respectively This

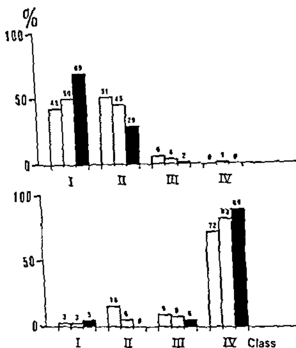


Fig 1 Separation of brain tumour cases (lower diagram) from control cases (upper diagram) by brain scintigraphy The interpretation results of group 1 (the most well trained interpreter ■) group 2 (the five well trained interpreters □) and group 3 (the five not well trained interpreters ▦) are classified according to Table 1 The relative number of cases in each class is indicated by the height of the columns.

subjective classification of brain scintigrams was intended to correspond well to the objective classification made by the symmetry detector method (LIND & LARSSON)

The interpreters were classified into groups 1, 2 and 3

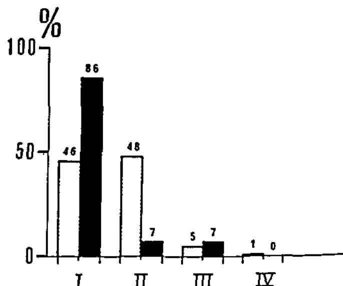
Group 1 The most experienced interpreter (4 years of general radiology, 20 years of neuroradiology)

Group 2 Experienced interpreters belonging to the permanent staff of the Department of Neuroradiology (more than 4 years of general radiology and 3 years of neuroradiology)

Group 3 Five less experienced interpreters, qualified general radiologists on postgraduate training in neuroradiology of less than 4 months duration (4 to 14 years of general radiology)

Results

The results of the classification made by groups 1, 2 and 3 appear in Fig 1 The most experienced interpreter (1) was most efficient in separating brain tumour cases from control cases, and the group of the least experienced interpreters (3) was least efficient in this respect It was concluded that the material used was comprehensive enough to permit demonstration of the difficulty of interpretation of brain scintigrams as well as the importance of long experience in the field of neuroradiologic diagnosis



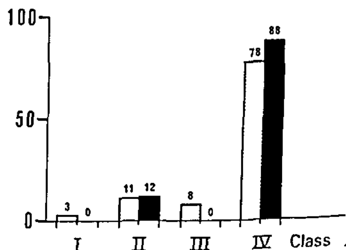


Fig 2 Separation of brain tumour cases from control cases by the objective symmetry detector method (■) and by scintigraphy (□) The subjective interpretations of all ten interpreters and the objective interpretation by the objective symmetry detector method are classified according to Table 1 and indicated with the control cases (upper diagram) and the brain tumour cases (lower diagram) The relative number of cases in each class is indicated by the height of the columns

The objective symmetry detector method was more efficient in separating brain tumour cases (group C) from control cases (groups A and B, respectively) than the group of all 10 interpreters of brain scintigrams (Fig 2) About 88 per cent of the 18 brain tumour patients was classified as definitely abnormal by the symmetry detector method, but only about 78 per cent of the 180 interpretations of scintigrams from the same brain tumour patients was classified as definitely abnormal Many control cases (group B) were not classified as definitely normal by the 10 interpreters (Fig 2)

Discussion

The diagnostic importance of gammaencephalography is unquestionable but it is important to compare different methods and also to optimize the techniques used for different diagnostic purposes In order to facilitate such a comparison of various methods, the aim of the examination as well as the concepts of sensitivity, detect-

ability and diagnostic accuracy should be defined as clearly as possible The primary purpose of gammaencephalography may be defined as that of separating patients with an abnormal distribution of the injected nuclide in the skull from cases with a normal distribution (diagnostic screening) In abnormal cases a further objective of the same or another procedure might be to obtain a topographic or etiologic differential diagnosis by a closer analysis of the pathologic accumulation of activity with regard to its distribution in space as well as its distribution in time after intravenous bolus injection of the nuclide

Sensitivity of an evaluation parameter is defined as the number of evaluation units per unit of evaluated effect of interest (for instance percentage increase of counts per minute per unit of local accumulation of nuclide in the brain)

Detectability of an evaluation parameter is defined as the size of the smallest evaluated effect of interest possible to detect outside the normal range with a significance, that corresponds to a certain number of standard deviations

The diagnostic error constitutes a measure of the diagnostic accuracy of a method, and may be defined as the region of overlapping of two curves which describe the distributions of results from normal cases as well as from patients with the pathologic effect of interest (for instance brain tumours)

The diagnostic accuracy (capacity to separate pathologic cases of interest from normal) of a method is sometimes inadequately estimated only from the relative number of pathologic cases with positive findings In addition, at least the relative number of both false positive and false negative cases should be presented in order to obtain an adequate description of the diagnostic accuracy (LUSTED 1968)

However, the separation of a group of patients with brain lesions from a group of normal cases theoretically can be illustrated by assuming the criterion parameter values of the two groups to be distributed as indicated in Fig 3 The degree of overlapping of the distribution curves in these figures indicates the diagnostic failure of the criterion parameter used It is evident from the figure that the choice of classification borders (Table 1) intended for medical decision making, should be influenced by the incidence of pathologic cases in the total case-material examined (Fig 3 a, b), as well as by the characteristics of the distributions of measuring results from the normal group and the pathologic group, respectively (Fig 3 a, c) Evidently, the diagnostic accuracy of a method is not adequately described by reporting the relative number of false positive and false negative cases only, but the relative number of borderline cases should also be reported However, the distributions of measuring results in the present series were based on a limited number of cases and therefore the scheme in Table 2 (instead of the curves in Fig 3) was used for comparing the diagnostic failure (accuracy) of the two methods

Reliability of results A comparison between different methods is basically dependent on the selection of cases examined, and this is one reason why it is almost impossible to make a relevant comparison between the results published by different authors

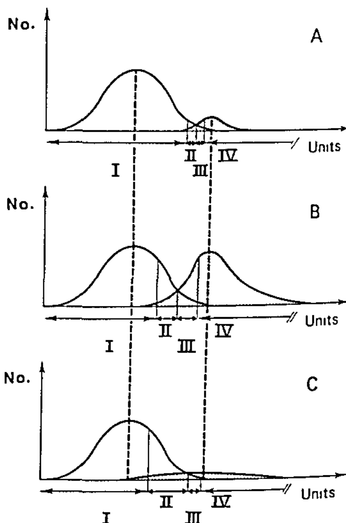


Fig 3 A hypothetical criterion parameter separating hypothetical populations of normal cases (white areas) and pathologic cases (hatched areas) The vertical lines and roman numerals indicate classification according to Table 1 A The relative size of the pathologic group is small as indicated by the small hatched area The curves fall abruptly when overlapping and the relative number of borderline cases is thus small B The relative size of the pathologic group is enlarged as indicated by the large hatched area and the curves fall abruptly when overlapping Hence, the classification borders are moved to the left and the number of borderline cases is larger C The relative size of the pathologic group is small as indicated by the small hatched area, but the curves slope gently downwards when overlapping The relative number of borderline cases is thus large

The brain tumour cases in this report were all later operated upon and the diagnoses confirmed by microscopy It is thus possible that very small tumours causing discrete symptoms not indicating surgery were excluded from the material Moreover, large tumours were excluded because they were inoperable The remaining group of tumour cases was regarded as roughly comparable with brain tumour cases appearing in a routine screening material, especially as there was no essential time lapse between the initial clinical examination that demonstrated the lesion and the gammaencephalography The same brain tumour cases were examined by both methods, but for practical reasons it was not possible to examine the same control cases by both methods Group A was without any symptom or sign of brain lesion (Lind et coll) Group B was examined with routine brain scintigraphy because of an epileptic attack or headache (Lind 1976) No other symptoms and no examination results suggested brain tumour or other gross lesion The routine brain scintigrams from these cases were rejected if not classified as normal by the initial clinical routine examination, the remainder was then regarded as control cases without brain

Table 2

Scheme suggested for describing and comparing the diagnostic failure of two methods The control cases and pathologic cases are classified according to Table 1 and the relative numbers of correct, in correct or borderline classifications are given in per cent for both methods

	Classification			
	Correct	Correct borderline	Incorrect borderline	Incorrect
Control cases				
Symmetry detector	86	7	7	0
Scintigraphy	46	48	5	1
Pathologic cases				
Symmetry detector	88	0	12	0
Scintigraphy	78	8	11	3

lesions Hence, some scintigrams from cases with a pathologic distribution of $^{99}Tc^{m}O_4$ in the skull might be included in group B, but on the other hand scintigrams of pathologic appearance were excluded from group B by the initial routine examination It should therefore be possible to regard groups A and B as comparable control groups, despite the different selection principles

The results of the brain scintigram classification were based on 740 classifications of control, undiagnosed and tumour cases randomized into one group The mean level of experience of brain scintigraphy in the ten interpreters was probably higher than might be expected to be available in routine screening work outside large neurologic centres The undiagnosed cases were included into the case material at the interpretational stage in order to avoid a too artificial patient material They were not included in the evaluation of diagnostic accuracy of the methods since in the end no definite diagnoses were reached despite meticulous clinic and neuroradiologic examinations

The interpreters became aware of the approximate proportions of pathologic and control cases in the material This might have influenced their estimations of probability (Fig 3) but on the whole this classification was assumed to correspond to the objective classification of the symmetry detector method (LIND & LARSSON)

The ten investigators were divided into groups 1 to 3 according to their experience in order to find out whether the material was sufficient to demonstrate differences in diagnostic accuracy between interpreters of different experience, in spite of the disadvantages of the patient material mentioned above and the small number of cases From Fig 1 it is evident that the material was sufficient to demonstrate the difficulties of brain scanning, and that the more experienced interpreters were more efficient in separating pathologic cases from control cases as compared to less experienced interpreters, albeit trained general radiologists

Diagnostic accuracy The same patient material was then used to compare the diagnostic accuracy of both methods It was found that the objective symmetry detector method was more efficient in separating the brain tumour cases from the control cases than was the group of all ten interpreters of brain scintigrams (Fig 2 Table 2) Although the interpretation of results from the symmetry detector method was made semiautomatically and objectively by a technical assistant, the method was at least as efficient in separating brain tumour cases from the control cases as the five well-trained neuroradiologists interpreting brain scintigrams (Figs 1, 2)

With the objective symmetry detector method fewer cases were classified as borderline cases, thus the information was easier to use in decision making (Fig 2 Table 2) This is especially advantageous if the method is used for general screening purposes because a large number of false positive or borderline cases would mar the purpose of screening as they necessitate further examination or clinical follow up There was no indication that the borderline classes II and III of the objective classification of the symmetry detector method were too narrow (LIND & LARSSON)

It is possible to change the objective classification borders of the objective symmetry detector method in order to obtain a controlled change of the relation between false positive and false negative cases (LIND) This is an advantage because the objective classification of the method can thus be adapted to different decision making situations, as for instance the screening of large materials with an expected low prevalence of brain lesions (Fig 3 a) or examination of neurologically strongly suggested tumour cases in order to decide on means of further examination (Fig 3 b) (LIND 1975)

The subjective interpretation of brain scintigrams has been shown to constitute a considerable source of variation which can be avoided by using the objective symmetry detector method (LIND 1976) In accordance with the definitions given, the elimination of subjective interpretation as one source of variation should improve the detectability of the objective symmetry detector method

It is thus reasonable to assume that the high diagnostic accuracy obtained by the objective symmetry detector method (Fig 2, Table 2) to a certain extent is explained by absent variation inherent in the subjective interpretation of results or by the high detectability of many evaluation parameters used (especially when based on side difference or concerning centrally located regions) (LIND & LARSSON)

However, the sensitivity of the objective symmetry detector method to some effects of interest is small compared to brain scintigraphy (for instance the shape of the boundaries of local accumulations of nuclide), and the normal variation of some evaluation parameters used (for instance close to the skull base) is probably larger In consequence, the low spatial resolution of the symmetry detector method and the detectability of evaluation parameters close to the skull base make it probable that conventional scintigraphic and gamma camera methods are the methods of choice for the special purpose of detecting local accumulations of nuclide close to the skull base (LIND 1975)

However, the overall diagnostic accuracy of the methods is not possible to estimate from calculations of their sensitivity and detectability but must be assessed directly from patient materials The results of the present series indicate that the less expensive objective symmetry detector method is the method of choice for general screening purposes, especially if interpreters with sufficient experience of brain scintigraphy are not available, which is often the case in the screening of large materials

This comparison of the objective symmetry detector method with a brain scanner is assumed to be relevant also for a comparison with gamma cameras and the autofluoroscope because previously published results indicate that there is no definite difference in diagnostic accuracy between brain scanners and gamma cameras and the autofluoroscope (PARK & MANSFIELD 1972, PEDERSEN & HAASE 1970)

Conclusions Subjective interpretation of brain scintigrams constitutes an important source of variation, possibly diminishing the all round diagnostic accuracy of brain scintigraphy

The diagnostic accuracy of the objective symmetry detector method for gammaencephalography was equivalent to or better than the diagnostic accuracy of conventional brain scintigraphy

The objective symmetry detector method for gammaencephalography, offering high diagnostic accuracy and not demanding large personnel, economic or technical resources is well suited to routine screening of brain lesions

SUMMARY

The diagnostic accuracy of brain scintigraphy and the objective symmetry detector method for gamma encephalography is compared The objective symmetry detector method was found more efficient in separating brain tumour patients from normal than a group of ten radiologists interpreting brain scintigrams

ZUSAMMENFASSUNG

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RESUME

L auteur a compare la precision diagnostique de la scintigraphie cérébrale et de la methode de detecteur objectif de symétrie pour la gamma-encephalographie La methode de detecteur objectif de symétrie s est montree plus efficace qu'un groupe de 10 radiologistes interprétant les scintigraphies cérebrales pour distinguer les malades ayant une tumeur cerebrale des sujets normaux

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SELECTIVE INTRAARTERIAL STEROID INJECTION IN ULCERATIVE COLITIS

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The diagnosis of ulcerative colitis has previously been made primarily by barium enema and endoscopy but more recently the importance of angiography has been emphasized

The angiographic findings in ulcerative colitis and therapeutic effect on that disease of steroid injection directly into the superior and inferior mesenteric arteries, which was first attempted and reported by BABA (1971) and BABA et coll (1974), are discussed in the present report

Material and Methods

Angiography with injections into the superior and inferior mesenteric arteries was performed in 11 patients (aged from 17 to 72 years) with microscopically proven ulcerative colitis In all of these patients, the diagnosis was made by endoscopy using a fibercolonoscope and biopsy and barium enema The patients had had symptoms and signs of the disease from 1 week to 6 years Oral administration of steroids had been used in all patients and steroid enema in 2 cases Most of the patients had not satisfactorily responded to the treatment.

In 10 cases steroid (Prednisolone 10 to 25 mg) was injected via the catheter selec-

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a

b



c

Fig 1 A 44 year old man with a 6 year history of ulcerative colitis Before selective steroid injection a) Barium enema Ulcerations and pseudopolypoid lesions b) Selective inferior mesenteric angiography early arterial phase Loss of normal tapering of the vasa recta in the left hemicolon Luminal irregularity in peripheral part of the vasa recta c) Late arterial phase Intense venous filling Prednisolone 10 mg was injected into superior and inferior mesenteric arteries during examination

Table 1

Measurement of caliber of inferior mesenteric artery

	No	Mean diameter (mm)	Range (mm)
Control group	32	4 1	3 0–5 0
Ulcerative colitis	11	5 7	4 0–6 5

tively into the inferior mesenteric artery, and in 7 cases steroid injection was made into both the inferior and superior mesenteric arteries The effect of these therapeutic procedures was measured as changes in the clinical condition and by barium enema and endoscopy In 4 cases, the angiographic examination was repeated to evaluate the therapeutic effect

Selective angiography was performed via the transfemoral route using a standard catheter (2 4 mm, 7 2 French) Thirty five ml Urografin 76 % (Schering, Germany) were injected into the superior mesenteric artery and 15 ml into the inferior mesenteric artery at a rate of approximately 7 ml/s

The angiographic films were analyzed for the following widening of inferior mesenteric arteries, loss of normal tapering of vasa recta, intense filling of the capillaries in the intestinal wall and early venous filling

The diameter of the inferior mesenteric arteries were measured and compared with a control group consisting of 32 patients with esophageal malignancy They were submitted to angiography of the colon before esophageal reconstruction using left hemicolon

Results

Loss of the normal tapering of the vasa recta was observed in all cases and in one case dilated vasa recta had irregular lumina (Fig 1) Intense filling of the capillaries was observed in 9 cases and early venous filling in 5

The width of the inferior mesenteric artery in patients with ulcerative colitis differed significantly from that in the control group (Table 1) This difference probably indicates an increased blood flow in this region

Steroid injections into the superior and inferior mesenteric arteries were made in 10 patients and the effect on the clinical signs appears in Table 2 Moderate improvement was obtained in 4 cases, and in 5 cases a marked improvement (Fig 2) The effects of the selective arterial injection of steroid usually appeared within 24 hours In one case the clinical symptoms remained unchanged even after a second injection into the superior and inferior mesenteric arteries

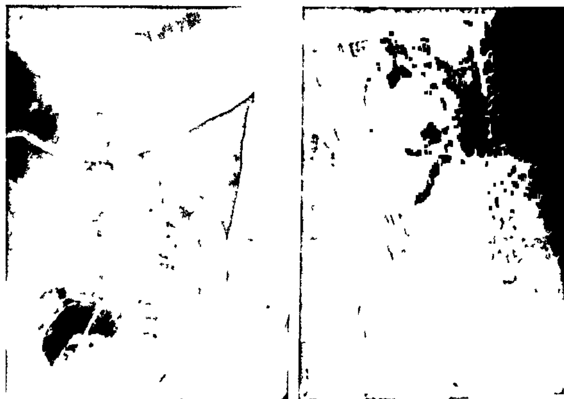


Fig 2 The same patient as in Fig 1, one month later a) Barium enema Ulcerations and pseudopolyposis have disappeared b) Selective inferior mesenteric angiography Normal tapering of vasa recta without luminal irregularity, no early venous filling

Discussion

The first description of the angiographic features in ulcerative colitis was made by ÖDMAN (1959), who reported that irregular widening of the vascular arcades in the colon with early venous filling occurred in patients with ulcerative colitis During the past few years this hypervascularity of the affected part of the colon in this disease has been confirmed angiographically (BOIJSEN & REUTER 1966, ERIKSON et coll 1970, LUNDERQUIST & LUNDERQUIST 1967, MARGULIS & HEINBECKER 1961), microscopically (WARREN & SOMMERS 1954) and microangiographically (SPJUT et coll 1964)

The angiographic findings are widening of arteries supplying the diseased area of the colon, loss of normal tapering of vasa recta, intense capillary filling in the intestinal wall and early venous filling BOIJSEN & REUTER and LUNDERQUIST & LUNDERQUIST emphasized that in ulcerative colitis widening of the vasa recta was not accompanied by irregular lumina and this might differentiate ulcerative from granulomatous colitis But ERIKSON et coll emphasized the difficulty in distinguishing these conditions

In the present material, increased caliber of interior mesenteric arteries and widening of vasa recta (loss of normal tapering) were observed in all cases, but early venous filling was noted in only 5 out of 11 cases

Table 2

Therapeutic effect of Prednisolone injection in 10 patients

Age and Sex	Dose and site of injection	Effect
39 M	Sup mesenteric art 15 mg Inf mesenteric art 15 mg	Marked
44 M	Sup mesenteric art 10 mg Inf mesenteric art 10 mg	Marked
27 F	Sup mesenteric art. 15 mg Inf mesenteric art 15 mg	Moderate
57 F	Sup mesenteric art 25 mg Inf mesenteric art 25 mg	Moderate
20 F	Sup mesenteric art 10 mg Inf mesenteric art 20 mg	Negative
72 M	Inf mesenteric art 15 mg	Moderate
30 M	Inf mesenteric art 20 mg	Marked
35 M	Sup mesenteric art 15 mg Inf mesenteric art 15 mg	Moderate
42 M	Inf mesenteric art 15 mg	Marked
17 F	Sup mesenteric art 20 mg Inf mesenteric art 20 mg	Marked

BACANER (1966) measured an increased blood flow to the colon in ulcerative colitis with an isotopic technique He suggested that most of this blood flow passed through arteriovenous shunts

In one of the present cases, the dilated vasa recta had some irregular lumina, which illustrate the difficulty in diagnosing this inflammatory disease using only angiography

The selective arterial injection of steroid (Prednisolone) into the inferior and superior mesenteric arteries was effective in 9 of the 11 patients In only one case was no improvement of clinical symptoms encountered

SUMMARY

Angiography was performed in 11 patients [illegible]
jected directly into the superior and inferior [illegible]
cularity of the affected regions was a common [illegible]
only 5 cases out of 11 Good results were obta[illegible]

ZUSAMMENFASSUNG

[illegible]

der betroffenen Abschnitte war ein gewohnlicher Befund, eine fruhzeitige venose Fullung wurde jedoch nur in 5 von den 11 Fällen beobachtet Gute Ergebnisse wurden durch intra arterielle Steroidinjektion erhalten

RÉSUMÉ

Les auteurs ont fait à 11 malades atteints de colite ulcéreuse une angiographie et ont injecté à 10 de ces malades de la prednisolone directement dans les artères mésenteriques supérieure et *inférieure* *L'hypervascularisation des régions malades est un signe fréquent, mais les* auteurs n'ont observé un retour veineux précoce que dans 5 cas sur 11 Les injections intra artérielles de stéroïde ont donné de bons résultats

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SPIGELIAN HERNIA

P M SOM, M T KHILNANI, B S WOLF and S L BERANBAUM

A Spigelian hernia is an external hernia through the anterior abdominal wall lateral to the linea semilunaris (semilunar line), first described by the Flemish anatomist Spieghel (SHEEHAN 1951, BAILEY & LONE 1949) Klinklosch (HOLLOWAY 1922) was the first to depict a spontaneous rupture along this line and gave it the proper name Spigelian hernia

The semilunar lines, one on each side, extend from the tips of the ninth costal cartilages to the pubic tubercles, marking the outer borders of the rectus sheath The structures involved in the formation of the rectus sheath are well known It is probably less well known that the blending of the muscle layers and aponeuroses at the margins of the rectus sheath is not accomplished through sudden sharp planes, but rather through a broad zone (AIRD 1949, HOLLOWAY) Usually the muscle bands of the internal oblique and transversus muscles traverse each other at definite angles, closing any gaps between muscle bundles and thus reinforcing each other However, in some people below the umbilicus these muscle bundles are superimposed and leave potential gaps which are easily split apart by small properitoneal lipomata or extraperitoneal fat, acting as wedges through these weak points The most common place is along the outer edge of the rectus sheath below the umbilicus where almost all Spigelian hernias occur (ZIMMERMAN et coll 1944, LEIS et coll 1958, KOONTZ 1952, MASON & RUGE 1948, WAKELEY & CHILDS 1951) The sac is formed by perito-

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der betroffenen Abschnitte war ein gewohnlicher Befund eine fruhzeitige venose Fullung wurde jedoch nur in 5 von den 11 Fallen beobachtet Gute Ergebnisse wurden durch intra *arterielle Steroidinjektion erhalten*

RÉSUMÉ

Les auteurs ont fait à 11 malades atteints de colite ulcereuse une angiographie et ont injecte à 10 de ces malades de la *prednisolone directement dans les arteres mésenteriques superieure* et inférieure L hypervascularisation des regions malades est un signe frequent mais les auteurs n ont observé un retour veineux precoce que dans 5 cas sur 11 Les injections intra artérielles de stéroïde ont donné de bons résultats

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Fig 1



Fig 2

Fig 1 Herniation of the sigmoid colon directed supero laterally Fairly wide hernia neck (→)
Fig 2 Spigelian hernia Narrow neck The sigmoid loop directed towards the ant sup iliac spine

often directed to the anterior superior iliac spine The upper loop of the herniated bowel has a smooth localized extrinsic impression of the thick aponeuroses of the internal oblique and transverse muscles This may lead to constriction of the upper loop at the hernia neck and result in obstruction This occurred in three of our cases, all of which were small bowel obstructions with narrow hernial necks The neck is often wide when colon lies in the hernia sac Obstruction in these circumstances is less frequent If the herniated colon has diverticuli, as often happens in the older age group, it may become fixed and the hernia irreducible if diverticulitis ensues Perforated diverticulitis may present as an anterior abdominal wall abscess

Inguinal hernias are slightly lower in position, pass inferiorly toward the groin and scrotum and are rarely interstitial They do not illustrate the characteristic sharp pressure defect only on the upper loop seen in Spigelian hernias Incisional hernias have wide necks and pass through all layers of the abdominal wall into the subcutaneous tissues A history of surgery in the immediate region will also be present Again, the extrinsic pressure defect is not seen on the upper loop

There is an unusual funicular type of direct inguinal hernia (MATHEWS 1923), that should be considered in the differential diagnosis These lesions resemble classical Spigelian hernias in that they arise adjacent to the linea semilunaris, near its termination The defects usually are small with firm edges giving rise to a high incidence of incarceration They may be multiple and appear to be acquired in nature with no

neum and occasionally includes fibers of the fascia transversalis If the apex of the *hernia sac is a lipoma, it will usually constitute the bulk of the hernia mass* In theory the sac could lie between the fascia transversalis and the m transversus abdominis or the m transversus abdominis and m obliquus internus In practice, however the sac lies almost exclusively between the internal and external oblique muscles (WATSON 1948, PAUL & SULLIVAN 1958) After bursting through the internal oblique muscle the hernia becomes interstitial and may continue to dissect laterally appearing most prominently in the region of the anterior superior iliac spine Some have been reported directed toward the bladder, the obturator foramen or between the external oblique and Scarpa's fascia A hernia under Scarpa's fascia is then called a Kuster's hernia Omentum and small bowel are the most common contents of the hernia sac (WAKELEY & CHILDS, RAVITCH & HITZROT 1960) Caecum and sigmoid occur less frequently Appendix and ovary have appeared in the sac Several authors (COOPER 1844, RIVER 1942, OLSON & DAVIS 1968) have suggested that this particular hernia is probably more common than is generally believed and that its recognition may be important as an occasional cause of abdominal pain and intestinal obstruction Bilateral Spigelian hernias and multiple hernias may be present (HOLLOWAY, READ 1960) There is no predilection as to the side of the abdomen involved The majority of cases are diagnosed in the fifth to sixth decades with extremes reported at age 10 years and 80 years Both sexes are affected equally

There are no characteristic symptoms and the hernias may be entirely asymptomatic The most common symptoms are localized pain or discomfort at the site of hernia protrusion, usually made worse by physical exertion Traction on omentum may produce nausea and vomiting As the hernia enlarges or perforates the external oblique muscle, a bulge can be noticed Incarceration or strangulation of the bowel within the hernial sac is not uncommon, due to the small rigid neck Richter type hernias, perforation, abdominal wall abscess and even finally fecal fistulas have been reported (MERSHEIMER et coll 1951)

Differentiation from a variety of abdominal wall tumors may be difficult or impossible clinically This hernia is cured by surgery and no recurrences are recorded in medical literature

Radiology

On a preliminary film, a loop of air filled bowel projecting laterally in either the left or right lower quadrant and lying superior and lateral to the usual position of either a femoral or inguinal hernia should strongly suggest the diagnosis of Spigelian hernia If the hernia is incarcerated or obstructed, the dilated loops of bowel proximal to the neck of the hernia become evident

Barium examinations reveal the characteristic appearance of the hernia The hernial opening is variable in size but usually it is narrow, measuring 1 to 2 cm Occasionally it can be up to 8 to 10 cm wide and then its lower margin approaches the inguinal ring The hernial opening is at or lateral to the linea semilunaris and is

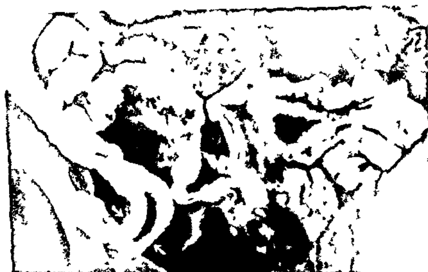


Fig 4 Spigelian hernia (neck→) on the right side at about the same level as an inguinal hernia on the left side The Spigelian *hernia directed* towards the ant sup iliac spine



Fig 5



Fig 6

Fig 5 Oblique view Spigelian hernia with obstruction of the small bowel *The air filled* herniated loop projected just above the *acetabulum* The bowel loop directed towards the ant sup iliac spine

Fig 6 Barium enema Normal colon *Reflux into small* bowel Spigelian hernia The herniated loop of the small bowel is not dilated fluid filled loops, however are seen just above the hernia



Fig 3 Spigelian hernia Narrow neck producing obstruction of the small bowel

obvious accompanying blood vessels They are distinguished by their appearance medial and inferior to the epigastric vessels and their penetration through the transverse aponeurosis or conjoint tendon without any muscular involvement They occur in a younger age group, predominantly in males Their origin appears to be due to fascial tears Since muscle banding and intermuscular fatty degeneration seem to play no role in their etiology it would seem logical to restrict the term Spigelian herniation to the classical connotation

Some illustrated cases are now reported

Case reports

Case 1 A 67 year old male was admitted in congestive heart failure While in the hospital, an asymptomatic left lower quadrant mass was noticed

Barium enema revealed herniation of sigmoid through the anterior abdominal wall (Fig 1) The hernia neck was fairly wide and located lateral and above the usual position of an inguinal hernia Many diverticula were present on the herniated loop of bowel, which was directed superolaterally The hernia did not reduce spontaneously or by palpation because of fixation due to adhesions, a not uncommon complication No obstruction although a temporary delay in the retrograde filling of the colon The greater pressure defect by the margins of the hernia was on the upper loop

Case 2 A 55 year old patient was admitted with left lower quadrant pain and a clinical diagnosis of diverticulitis There was no history of previous abdominal surgery

Barium enema revealed herniation of sigmoid (Fig 2) The hernia neck was narrow and



F g 4 Sp gel an he n a (neck—>) on the r ght s de at about the same level as an ngu nal hern a on the left s de The Sp gel an hern a d rected towards the ant *sup il ac sp ne*



F g 5



F g 6

F g 5 Obl que v ew Spigel an hern a w th obstruct on of the small bowel The a r f lled hern ated loop p ojected just above the acetabulum The bowel *loop* d rected towards the ant sup iliac sp ne

F*ig 6 Bar* um enema Normal colon Reflux nto small bowel Sp gel an hern a The hern ated loop of the small bowel is not d la ed flu d f lled *loops, howe er are* seen just above the hern a



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Fig 7 A small Spigelian hernia simulating an inguinal hernia

located lateral and above the usual location of a femoral or inguinal hernia The unobstructed sigmoid loop was directed toward the anterior superior iliac spine The narrowing of the proximal loop of sigmoid was caused by the rigid margin of the hernia ring

Case 3 A 63 year old male was admitted with abdominal pain, vomiting and signs of intestinal obstruction A tender left lower quadrant mass was palpated

Preliminary examination of the abdomen revealed small bowel obstruction Barium examination of the small bowel demonstrated herniation of a short segment of ileum through the anterior abdominal wall in the left lower quadrant The neck of the hernia was narrow producing obstruction (Fig 3) The small bowel above the hernia was more dilated than the herniated segment, while contrast medium did not pass beyond the herniated loop The pressure defect was equally marked on both the cephalad and caudad end of the herniated loop The intervening space between the two ends of the loop was occupied by mesentery of the small bowel The site of obstruction was at the lower end of the loop and because of limited space in the sac, the loop itself was not dilated to the same extent as the proximal small bowel

Case 4 A 45 year old male was admitted for evaluation of anemia

Barium enema revealed diverticulosis of the colon A barium meal revealed an asymptomatic left inguinal hernia and an asymptomatic right Spigelian hernia The neck of the Spigelian hernia was located at about the same level as the inguinal hernia on the left side However, the hernia was directed toward the anterior superior iliac spine (Fig 4), while the inguinal hernia bowel loop was directed toward the scrotum

Case 5 A 47 year old female presented with abdominal pain, vomiting and abdominal distention

Barium enema revealed diverticulosis of the colon and dilated small bowel loops The oblique film (Fig 5) revealed the cause of the obstruction to be a herniation of small bowel

through the anterior abdominal wall in the right lower quadrant The air filled herniated loop was projected over the right iliac bone just above the acetabulum It had the characteristic arcuate configuration and orientation with the bowel loop directed toward the anterior superior iliac spine The contrast medium could not be forced through the caudad end of the herniated loop

Case 6 A 52 year old male presented with nausea and vomiting A left lower quadrant tender mass was palpated There was no history of previous surgery The clinical impression was that of diverticulitis

Barium enema revealed a normal colon There was reflux into the small bowel which was located lateral to the sigmoid colon in the left lower quadrant A loop of small bowel not significantly dilated was directed toward the anterior superior iliac spine and fluid filled loops of small bowel were lying just above the herniated loop (Fig 6) A diagnosis of Spigelian hernia with obstruction was made at surgery

Case 7 A 37 year old female presented with left lower quadrant pain and nausea

Barium enema revealed a Richter's type hernia of the sigmoid colon with compression of the lumen and wall of the bowel There was no obstruction

At surgery a small Spigelian hernia was found (Fig. 7)

This case illustrates that although classical Spigelian hernias are directed toward the anterior superior iliac spine, a small hernia may simulate the appearance of an inguinal hernia

SUMMARY

The specific anatomy of the linea semilunaris is presented How this anatomy pertains to the development of a Spigelian hernia is reviewed The characteristic radiographic appearance of Spigelian hernia, is presented with illustrated cases The differential diagnosis is discussed It is often possible to diagnose a Spigelian hernia radiologically, which may be a difficult clinical diagnosis

ZUSAMMENFASSUNG

Die spezifische Anatomie der Linea semilunaris wird beschrieben Wie sich diese Anatomie zur Entwicklung der Spieghelschen Hernie verhält wird zusammenfassend dargestellt Das charakteristische rontgenologische Bild der Spieghelschen Hernien wird an Hand illustrierender Fälle gegeben Es wird die Differentialdiagnose diskutiert Es ist oft moglich, die Hernie rontgenologisch zu diagnostizieren, was eine schwierige klinische Diagnose sein kann

RÉSUMÉ

Les auteurs presentent l anatomie specifique de la ligne semilunaire Ils exposent comment cette anatomie a un rapport avec le developpement d'une hernie de Spigel Ils presentent l aspect radiologique caracteristique des hernies de Spigel avec des exemples Ils etudient le diagnostic differentiel Il est souvent possible de faire radiologiquement le diagnostic de hernie de Spigel, diagnostic qui peut être difficile par la clinique

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REPEAT SCINTIGRAPHY OF THE INTERNAL MAMMARY LYMPH NODES IN RABBITS

K JONSSON, N O BERG, T LANDBERG, S E STRAND and GUDRUN SVAHN-TAPPER

Biopsy and surgical exploration have demonstrated that the internal mammary nodes often contain metastatic deposits in carcinoma of the breast (HAAGENSEN et coll 1972) The frequency of such metastases is correlated with the location of the tumour in the breast and with the microscopic findings in the axillary lymph nodes The exact prognostic and therapeutic implications of internal mammary node metastases is not fully known The nodes are often included in pre or postoperative radiation therapy of malignancy of the breast A method for selection of patients who might benefit from such treatment would be of great value

Different methods have been developed for detection of metastases in internal mammary nodes HANDLEY & THACKRAY (1949 1954) made biopsy of the internal mamm[illegible]
tor [illegible]
bee[illegible] ...ed as a method to detect metastases (CHERNOMORDIKOVA et coll 1972) KETT et coll (1970) described direct lymphography of the breast and TAENZER & MEYER BURG (1974) a method where lymph vessels on the liver convexity were cannulated through a laparoscope The lymph vessels of the liver capsule drain to the parasternal (internal mammary) chain of lymph nodes The most common

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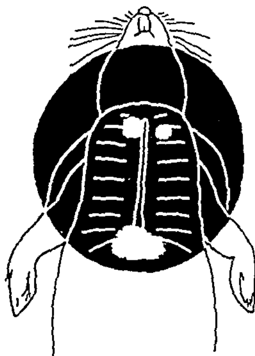


Fig 1 Scintigraphy of the thorax and upper part of the abdomen following injection of 250 μCi $^{99}Tc^{m}$ S-colloid subcutaneously on both sides of the xiphoid process

method to examine the internal mammary nodes, except biopsy, is lymph scintigraphy, where the nuclide is injected subcutaneously on both sides of the xiphoid process or behind the process This method was first described using colloidal ^{198}Au (SCHENK 1966, SCHENK et coll 1966, ROSSI & FERRI 1966) GÖRANSON & JONSSON (1974) used $^{99}Tc^{m}$-S colloid, and the experimental and clinical evaluation of the method has been reported by GÖRANSON et coll (1973) and by GÖRANSON & JONSSON (1974 a, b, c)

Irradiation may be expected to cause an alteration in the uptake of nuclide in the internal mammary nodes After irradiation of lymph nodes in rats with 3000 R (200 keV and HVL 1 05 mm Cu) given in one fraction, ENGESET (1964, 1966) found an initial cellular depletion on the first day, followed by a cellular repopulation in the next ten days, and thereafter a further slow and permanent decrease in the cellular contents of the lymph nodes A slow, progressive induration of connective tissue occurred and some of the sinuses were destroyed after a few weeks Fractionation with 10×600 R or 5×600 R gave qualitatively similar results, though with 5×600 R the changes were less marked No or slight changes were encountered in the lymphatic vessels SHERMAN & O'BRIEN (1967) reported similar findings at the examination of the lymphatic vessels of dogs after irradiation with single doses of different sizes

In the rabbit, chest wall incision (GORANSON & JONSSON 1974 b) caused slight or no changes of the scintigraphic appearances of the internal mammary nodes

The scintigraphic appearances of the internal mammary nodes in rabbits at primary examination following chest wall incision and radiation therapy will now be reported

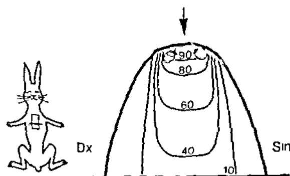


Fig 2 Distribution of absorbed dose in a transverse section of a rabbit ^{137}Cs Field size 3 5cm × 8cm SSD 20 cm

Material and Methods

Rabbits weighing about 4 kg were used for the experiments The animals had a free supply of laboratory food and water They were anesthetized with intravenous pentobarbitone sodium (Membumal-natrium, ACO, Sweden) at each scintigraphy, surgery, or radiation treatment

The scintigraphy was performed by the method of GÖRANSSON & JONSSON (1974 a) ^{99}Tc^{m} S-colloid was prepared according to PERSSON & NAVERSTEN (1970) The colloid contained an activity of 500 μCi/ml In the colloid was dissolved 200 IU of hyaluronidase (Hyalas, Leo, Sweden) per ml Half a milliliter of the colloid was injected subcutaneously on each side of the xiphoid process The animals were placed in supine position under a pin hole collimator of a gamma camera (Nuclear Chicago, Pho/Gamma III HP) The uptake of the colloid in the internal mammary lymphatics was followed for 15 to 60 minutes A typical scintigraphic image is presented in Fig 1

The radiation treatment was given with a ^{137}Cs source at SSD 20 cm The size of the collimator was 3 5 cm × 8 cm, and the cranial border of the field was a few millimeters above the suprasternal notch The distribution of the absorbed dose in a

Table 1

Distribution of 18 rabbits on different combinations of scintigraphy, chest wall incision and irradiation Microscopy was performed in all groups

Group	No of animals	Initial procedure	Irradiation	Rest period	Later procedure
1	3	—	—	—	—
2	4	—	—	—	Scintigraphy
3	2	Scintigraphy	—	8 weeks	—
4	2	Scintigraphy	—	8 weeks	Scintigraphy
5	3	Scintigraphy	3 weeks	5 weeks	Scintigraphy
6	4	Scintigraphy + Chest wall surgery	3 weeks	5 weeks	Scintigraphy

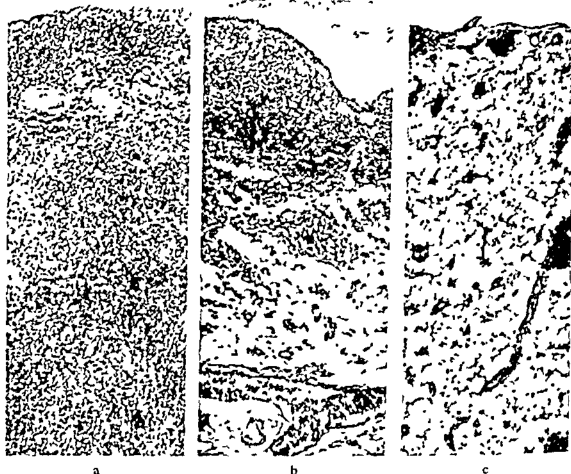


Fig. 3 Variation of lymph node structure in experimental animals a) High cellularity of cortex and medulla (Group 5 scintigraphy irradiation scintigraphy) b) Cortex cellular and medulla acellular and sinusoidal (Group 3 scintigraphy rest period) c) Node with mainly reticular sinusoidal structure and thin cortex (Group 3 scintigraphy rest period) 115

transversal section of a rabbit appears in Fig 2 Totally 10 fractions were given over 22 days, the peak absorbed dose at each fraction being 490 rad, total by 4 900 rad If the 80 per cent isodose curve is taken as representative target absorbed dose to the internal mammary nodes, then the absorbed dose to the nodes would be 3 900 rad in 10 fractions over 22 days In human connective tissue this would correspond to CRE 1 600 reu, which is a CRE often applied to the internal mammary nodes in the treatment of carcinoma of the breast in Sweden

The chest wall incision was 6 cm long and about 1 cm deep, extending down into the pectoral muscle It was placed 1 to 2 cm laterally of and parallel to the midline and was made under sterile conditions The wound healed during one week before irradiation was started

The series consisted of totally 18 rabbits Fifteen were divided into 6 different gro[illegible] subjected to different combinations (Table 1) of scintigraphy, chest w[illegible]d irradiation, whereas 3 served as control for microscopy

Table 2

Summary of microscopic findings

	Group	No of animals	No of lymph nodes	Main structure of lymph nodes: High cellularity in cortex and medulla	Cortex cellular, medulla sinusoidal	Nodes mainly sinusoidal	Nodes not scored	Focal reticulosis or fibrosis	Erythrophagocytosis	Pigmented cells	
Controls	1	3	8	4	4	0	—	1	—	1	
Scintigraphy only	2	4	20	7	9	4	—	2	10	3	*
	3	2	8	5	2	1	—	—	—	—	
	4	2	9	3	5	0	1	1	3	1	
Total		8	37	15	16	5	1	3	13	4	
Irradiated	5	3	13	5	4	3	1	2	2	3	**
	6	4	14	7	6	1	—	1	9	—	*
Total		7	27	12	10	4	1	3	11	3	

* Polynuclear in one node

** Polynuclear in one node and many mast cells in one node

When the animals were killed the breast plate from the upper thoracic aperture to the diaphragm was removed with the skin in situ and fixed in formol 10%. After fixation the soft tissue behind the breast plate including the central part of the intercostal tissue was cut at right angles to the vessels in slices 2 mm thick. These were blocked in paraffin. Sections 5 to 7 μ thick were cut and stained with Haematoxylin and Safranin van Gieson stain, reticle staining according to Gridley as well as with Giemsa stain for details of lymphoid cells. At microscopy special regard was paid to preservation of lymphoid tissue, in cortex as well as in medulla, to preservation of sinuses, reticulin and fibrous elements, to presence of erythrocytes in sinuses and phagocytes and of pigmented histiocytes as well as polymorphonuclear leucocytes.

Results and Discussion

The initial scintigraphy was normal, i.e. one lymph node on each side of the cranial part of the sternum being observed, in all animals except two, where uptake was noted only on one side. Following irradiation only and irradiation combined with chest wall incision, the scintigraphy was normal in all animals. One of the rabbits with only unilateral filling was examined microscopically without further scintigraphy, whereas the other at repeat scintigraphy presented a row of filled lymph nodes parallel to the sternum on the primarily unfilled side. One animal with initially bilateral filling had at repeat scintigraphy only unilateral filling.

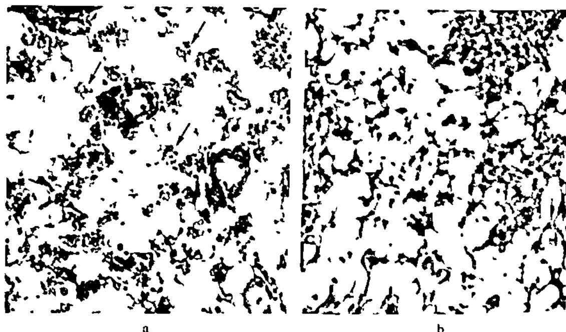


Fig. 4. a) Clustering of erythrocytes (→) in lymph node 2 hours after scintigraphy with haemorrhage at site of injection (Group 2 — not irradiated). b) Lymph node with a few erythrocytes in sinusoids but no clustering (Group 6 — irradiated lymph node). × 250.

Microscopy demonstrated marked variation in size, cellularity, and shape of lymph nodes in the unirradiated as well as in the irradiated groups (Table 2). Slight focal fibrosis was a rare finding and was seen also in one unirradiated animal. In about 50 per cent of the rabbits the caudal part of the thymus was included in the most cranial tissue block and in two irradiated animals distinct atrophy of lymphoid cells and fibrosis were found in a small part of the thymus. No consistent difference between irradiated and unirradiated rabbits was found on analysis of the largest diameter of the lymph nodes in the sections (Table 3). On the other hand, within 2 hours of scintigraphy (Groups 2 and 4 to 6, Tables 1, 2) a marked erythrocytosis of the nodes occurred, especially in the sinuses, and erythrocytes could also be found in parasternal lymph vessels. Most of these erythrocytes were clearly attached

Table 3

Size of lymph nodes examined microscopically

	Group	No of nodes	Nodes per animal	Largest diameter of nodes		
				> 2 mm	2 to 1 mm	< 1 mm
Controls	1	8	2·7	1	4	3
Scintigraphy only	2 + 3 + 4	37	4·6	12	12	13
Irradiated	5 + 6	27	3·9	8	14	5
Total		72	4·0	21	30	21

to the cells in the walls of the sinuses or in the reticular tissue of the lymph nodes (Fig 3) In only a few animals was erythrophagocytosis accompanied by leucocytosis (Table 2) The same frequency of erythrocytosis was found in irradiated animals as in the unirradiated ones, 42 and 45 per cent, respectively In the irradiated animals fewer erythrocytes were observed in the sinuses and the phagocytosis was less marked (Fig 4) Slight pigmentation occurred in most nodes, more marked pigmentation is indicated in Table 2 Only part of the pigment was Fe positive No correlation existed between pigmentation and previous scintigraphy or irradiation

The microscopic abnormalities of the lymph nodes following irradiation differed in the present series in many ways from those reported by ENGESET (1964, 1966) The difference may be due to different types of fractionation of the irradiation, different length of observation time, or to the fact that different species of animals were used ENGESET (1966) also found that after irradiation of lymph nodes their barrier function for erythrocytes but not for small charcoal-particles was reduced The less marked erythrophagocytosis in irradiated lymph nodes in the present series may still be in line with the findings of ENGESET

Thus previous scintigraphy, fractionated irradiation, and surgical trauma to the chest wall did not seem to give any changes that might influence the scintigraphic appearances on repeat scintigraphy of the internal mammary nodes in rabbits

SUMMARY

Rabbits were subjected to different combinations of scintigraphy of the internal mammary lymph nodes fractionated irradiation and surgical trauma to the chest wall No influence could be demonstrated on the image at repeat scintigraphy of the internal mammary nodes Microscopic changes in the lymph nodes and vessels were relatively slight and inconstant

ZUSAMMENFASSUNG

Kaninchen wurden verschiedenen Kombinationen von Szintigraphie der inneren Lymph knoten der Brustwand fraktionierter Bestrahlung und einem chirurgischen Trauma der Brustwand unterzogen Es konnte kein Einfluss auf das Bild bei wiederholter Szintigraphie der inneren Lymphknoten nachgewiesen werden Mikroskopische Veranderungen in den Lymphknoten und Gefassen waren relativ geringfugig und nicht konstant

RÉSUMÉ

Des lapins ont été soumis à différentes associations de scintigraphie des ganglions lymphatiques mammaires internes d irradiation fractionnée et de traumatisme chirurgical de la paroi thoracique La scintigraphie repétée des ganglions mammaires internes n a pas montre d influence de ces interventions sur l image Les modifications microscopiques des ganglions lymphatiques et des vaisseaux sont relativement legeres et inconstantes

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LYMPHANGIOGRAPHIC CRITERIA OF METASTASES

An evaluation of patients with malignant testicular teratoma

J GÖTHLIN and K JONSSON

The lymphangiographic diagnosis of metastases in lymph nodes is difficult Several criteria have been described often without adding much to the accuracy of the diagnosis Standardized criteria for facilitating the evaluation of metastatic spread to lymph nodes have been proposed by GÖTHLIN & FUCHS (1973) The materials of testicular teratoma assembled in two university hospitals have been reevaluated on these principles

Material and Methods

Lymphangiography was performed in 38 patients with malignant testicular teratoma and in 3 patients with malignant testicular teratoma mixed with seminoma Corroboration of the lymphangiographic findings were made at retroperitoneal lymph node dissection in 38 patients and at autopsy in 3 Inferior cavography was performed in 29 patients and urography in 30 patients

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Table 1

Diagnostic criteria

Criterion No	Changes in size and form of lymph nodes	Value
1	Smallest diameter 10 mm	+
2	Globular form	+
3	Filling defects, sharply demarcated, *with obliteration of intermediary sinus*	
	a) < 5 mm, solitary	+
	b) < 5 mm, multiple	+ +
	c) 5–10 mm, solitary	+ +
	d) 5–10 mm, multiple	+ + +
	e) > 10 mm, solitary, multiple	+ + +
4	Obstruction of lymphatics	
	a) Contrast medium in lymph vessels during storage phase	+
	b) Obliteration of lymph vessels	+ +
	c) Obstruction with collateral circulation	+ + +
5	Displacement of lymph vessels and nodes	+
6	Non filled chain of lymph nodes (Criterion 6 not originally included)	+ + +

Reliability of the positive lymphangiographic findings total value + + +, or more 95 %, + + + + 70 %, suggestion, + negative

The lymphangiographic films were reevaluated on the criteria presented in Table 1, without knowledge of the findings at operation or autopsy

The technique of lymphangiography was the common one using 1 to 2 ml of 1 % methylene blue in 0 5 ml lidocaine subcutaneously injected between the first and second toe for identification of the lymph vessels Following transverse incision of the skin in local anaesthesia, a 27 or 30 gauge needle was inserted into a free dissected vessel, and 6 to 8 ml of Lipiodol Ultrafluid were injected bilaterally at a rate of 4 ml per hour At the end of injection, a p , right and left oblique films of the pelvis and paraaortic regions were obtained The patient was reexamined 24 hours later with films exposed in the same projections

Results

In 13 patients the lymphangiographic appearances were considered normal, corroborated at retroperitoneal lymph node dissection

In 28 patients the lymphographic finding was abnormal, corroborated in 23 at surgery and in 3 at autopsy (Table 2) The most common combinations of abnormality were 3d or 3e with 4*b* and *c* or 5 (Table 1), giving a total value of + + + + + or

Table 2

Positive and negative findings at lymphography, operation and autopsy

Lymphangiography				Operation		Autopsy		False findings at lymphography			
A		B						A		B	
Pos	Neg	Pos	Neg	Pos	Neg	Pos	Neg	Pos	Neg	Pos	Neg
23	18	28	13	23	15	3	0	1	6	0	3

A according to criteria 1 to 5
B with the criterion non filled lymph nodes included (6)

more In one patient unsatisfactory filling of the lymph nodes did not permit diagnosis

One lymphography proved to be false positive, due to a lymph node erroneously considered as displaced and thus suggesting metastasis In 6 patients the lymphographies proved to be false negative, in 3 patients dependent on non filled lymph nodes (Fig 1) If these cases are excluded, the number of false negative lymphographies are reduced to 3, one classified as possible metastases, another one with bilateral metastases diagnosed on only one side, and the third, where paraaortic metastases diagnosed bilaterally turned out to be present only on one side From therapy planning only 2 patients could be classified as false negative and false positive, respectively, even if metastases were suggested in the first one

Discussion

The lymphatics draining the testis accompany the spermatic artery and vein to lumbar lymph nodes, normally present at the level of the renal vein (ROUVIÈRE 1932), although BUSCH et coll (1965) reported that the appropriate lymph nodes may be found to extend from Th11 to L4 on the ipsilateral side At lymphography in testicular teratoma this area is thus the main focus of interest However, crossing over of lymphatics from the right to the left side is common (BUSCH & SAYEGH 1963, SEITZMAN & HALLABY 1964, BUSCH et coll, WAHLQVIST et coll 1966, KÖRNER & HILWEG 1968 BURGENER & FUCHS 1969, WALLACE 1969, MAIER & SCHAMBER 1972, HULTEN et coll 1973) Thus metastases present in the left paraaortic lymph nodes may have their origin in right primary tumors

On analysis of the criteria of metastases given in Table 1, it is interesting to find that those classified as number one and two were not encountered They are probably of no value as they have not been observed in other similar materials (JONSSON et coll 1973, VON FISCHER et coll 1974, ZINGG et coll 1974) Filling defects with a diameter less than 5 mm may suggest metastases provided they are multiple Solitary

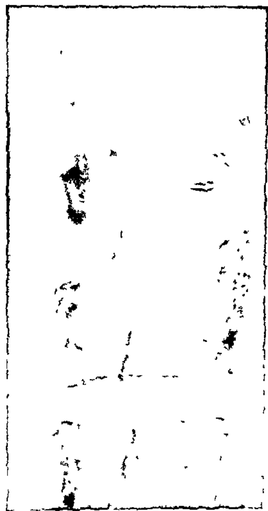


Fig 1



Fig 2

Fig 1 Defect filling of lymph nodes (→) at L2 Metastases at the same site at operation

Fig 2 Displacement of lymph nodes and filling defects right, displacement of a lymph node left (→) Bilateral retroperitoneal metastases at operation

defects (Fig 4) with a diameter between 5 and 10 mm should also be considered suggestive and regarded unequivocal if multiple (Fig 3) Filling defects must be sharply demarcated and obliterate the intermediary sinus to be classified as metastases Uncharacteristic defects located centrally in paraaortic lymph nodes are common and usually due to fibrolipomatosis or unspecific inflammation

Contrast medium retained in lymph vessels distal to the lymph nodes on the 24 *hour films* has no diagnostic significance This feature is especially common in the area distal to inguinal lymph nodes, which often demonstrate fibrolipomatosis or reactive hyperplasia Obstruction and displacement of lymph vessels or lymph nodes (Fig 2) and collateral circulation (Fig 3) are indicative of metastases, especially obstruction combined with collateral circulation However, the normal crossing of lymph vessels from right to left must not be considered as collateral circulation If such a crossing is absent a suggestion of metastases on the left side is well-founded

Deviation of cisterna chyli from its normal midline position has been reported as a sign of retroperitoneal masses by JONSSON et coll In the present material, however,



Fig 3

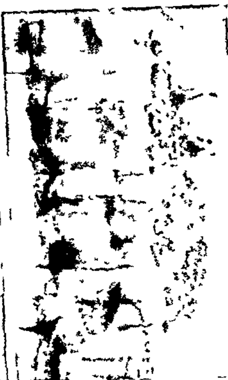


Fig 4

Fig. 3 Obliteration and displacement of lymph vessels and nodes left (→) Filling defects in several lymph nodes (↔) Metastases demonstrated at autopsy

Fig. 4 Large filling defects in 2 lymph nodes in the upper one lipping indicating an expansive lesion.

the diagnosis was reached without this sign which is inconstant as the cistern may be filled in only 30 per cent of cases at lymphangiography (FUCHS & GALEAZZI 1970)

Non filling of lymph nodes proved to be diagnostic in 3 patients (Fig 1) In one patient no filling was obtained because of unsatisfactory technique To the originally proposed criteria should be added non filling of lymph nodes if the technique is optimum KÖRNER & HILWEG HINTZEN et coll (1971) and MAIER & SCHAMBER considered the absent filling of a group or chain of lymph nodes to prove disease, but WALLACE and FUCHS (1970) have given it minor diagnostic significance because of the great variability of the lymph node anatomy

Cavography did not yield any information which was not obtained by lymphography In one patient, however, urography revealed an impression in the left ureter with no concurrent evidence of lymphangiographic abnormality The findings at urography are often difficult to evaluate as the normal course of the ureter varies

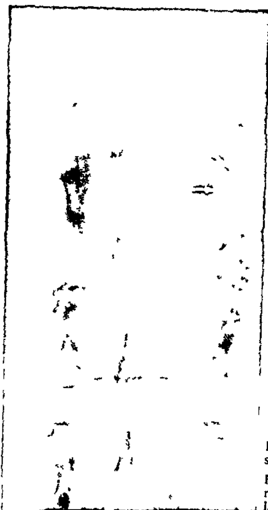


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widely. However, BAUM et coll. (1963) and HOPF & FUCHS (1970) claim that the combination of lymphangiography, inferior cavography and urography increased the information gained in about 10 per cent of the cases. In the present material such additional information was obtained in 2 patients although it was of no significance in planning of the treatment.

Conclusion

In teratoma of the testis, lymphangiography evaluated according to the proposed scheme with addition of the criterion of non-filled paraaortic lymph nodes provides for a high degree of accuracy. The scheme should facilitate the evaluation especially when the experience of this type of examination is limited.

SUMMARY

Lymphangiography of 41 patients with malignant testis teratoma has been analyzed according to a standardized scheme. The degree of accuracy, assessed at surgery or autopsy, in diagnosis of metastatic spread was high.

ZUSAMMENFASSUNG

Die Lymphangiogramme von 41 Patienten mit malignen Hodenteratomen wurden nach einem standardisierten Schema analysiert. Der Grad der Genauigkeit, festgestellt bei der Chirurgie oder Autopsie, bei der Diagnose von metastatischer Ausbreitung war hoch.

RÉSUMÉ

Les lymphographies de 41 malades atteints de tératome malin du testicule ont été analysées suivant un schéma standardisé. Le degré d'exactitude dans le diagnostic de la dissémination métastatique, controlé par l'intervention ou par l'autopsie, est élevé.

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PHARMACOANGIOGRAPHY IN EXPERIMENTAL TUMOURS

Evaluation of vasoactive drugs

L EKELUND, J GÖTHLIN N JONSSON and H O SJÖGREN

Several vasoactive drugs have been used in connection with angiography to enhance demonstration of tumour vascularity Vasoconstrictors as well as vasodilators have been reported to be of value With few exceptions, however, no comparison of their effect in the individual case seems to have been undertaken As experimental tumours should provide an excellent model for such comparisons, the investigation now reported was carried out

Material and Methods

Rats of inbred Wistar/Furth strain were used Five rats with kidney tumours induced by dimethylnitrosamine (DMN) were examined 8 months after introduction of the carcinogen (MAGEE & BARNES 1962, EKELUND & JONSSON 1971), 2 rats one week after intrarenal injection of 10^6 living cells of a colon adenocarcinoma induced with N methyl N[1] nitro-N nitrosoguanidine and further 2 rats one week after intrarenal injection of 10^6 living cells of a polyoma virus induced kidney sarcoma (BANSAL et coll 1972 STEELE & SJÖGREN 1974) Ten rats were examined 7 to 14 days after intraportal injection of 10^6 living colon carcinoma cells The 9 rats with renal tumours

Submitted for publication 3 April 1975

Book review

RÖNTGENDIAGNOSTIK VISZERALER VERLETZUNGEN NACH STUMPFEM ABDOMINALTRAUMA By M Haertel 108 pages with 60 figures Georg Thieme Verlag, Stuttgart 1974 Price DM 98 —

The author is a member of the staff of the University of Bern Traumatic lesions of the abdomen, especially those caused by blunt trauma, are the subject of this monograph These injuries are serious and the patients are often in a bad condition An exact radiologic diagnosis without waste of time is decisive for the correct choice of treatment A monograph of this type should thus fill a need

The material includes 150 cases, about 60 per cent with visceral lesions A graphic presentation of the material is given with regard to the type of trauma The traffic accidents dominate but it is surprising that cases with a criminal background are not separated

The main interest in this book is concentrated on angiography Lesions of the spleen and the liver are discussed thoroughly as well as injuries to the intestino mesenterial region A series of well selected cases is presented The pancreatic lesions are relatively few but interesting The angiographic findings are especially well discussed and illustrated Kidney lesions are described in detail on the basis of a material of about 60 cases

Traumatic abdominal lesions are often combined with lesions of the diaphragm and thorax Such combined lesions are only slightly touched upon The accidents are often complicated and abdominal lesions can seldom be looked upon separately Lesions in the lower pelvis, e g of the bladder, as well as ureteral lesions are not easy to explorate by angiography and have not been much discussed

The illustrations are of a high typographic quality Reproductions with magnified details of interest give the reader much information In some cases contrast levelling with contour enhancing has been used, the results of this technique may be questioned A graininess visible in some of the illustrations is caused by the radiographic quantum noise and a high contrast in connection with enlargement

Although angiography is important, certain types of diagnosis cannot be covered by this technique Conventional methods still are of value and angiography as well as other more special examinations can sometimes be impossible to carry out The demonstration of abdominal free gas and similar conventional examinations are not described at all It must also be pointed out that the angiographic methods require a well trained staff ready for full time activity Also economical aspects ought to be considered In certain cases the main problem is to decide if a surgical exploration is necessary or not—rather simple diagnostic methods may be satisfactory for that purpose It might be easy to forget the simpler methods if a highly sophisticated radiology is easily available The use of a needle for puncture of the abdominal cavity under fluoroscopic control may be the simplest and most rapid way to discover the presence of free blood

Complementary techniques to the conventional radiologic methods, which also may be used as substituted for radiology, i e scintigraphy and ultrasound, have not been discussed at all They ought to be under the responsibility of the radiologist Scintigraphy of the liver, spleen and kidneys may give important information in many cases without more time-consuming and for the patient more unpleasant examinations

To sum up, this monograph gives the reader a good information about the use of angiography but it is not a complete textbook of radiology of traumatic abdominal lesions The list of references is extensive

Ove Mattsson



Fig 2 Large r chly vascular zed DMN nduced renal tumour of the ep thel al type Late phase of select e ang o-graphy of the r ght k dney a) Control ser es b) After ang otens n c) After norep nephr ne d) After vasopress n e) After tolazol ne Only tolazol ne w th out effect as compared to control ser es

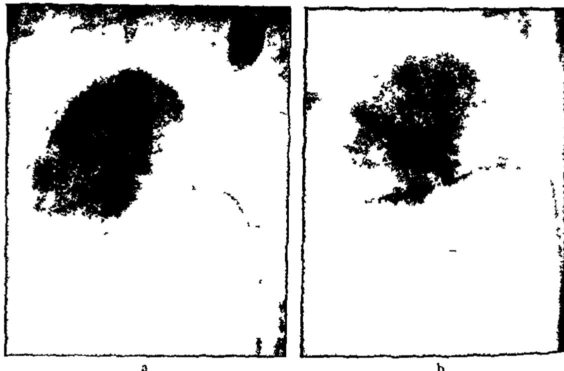


Fig 1 Selective angiography of the right kidney 8 months after DMN Poorly vascularized tumour in lower pole of the kidney a) Control series b) After injection of 0 0025 µg of angiotensin in the renal artery More tumour vessels revealed The other drugs without effect

were examined by selective nephroangiography and the 10 rats with liver tumours by coeliac or selective hepatic angiography

The technique for selective catheterization of the renal and coeliac arteries in the rat, enabled by magnification fluoroscopy, has been described previously (EKELUND & OLIN 1970) Ether anaesthesia was employed and films of the kidneys were exposed in a p projection, films of the liver in the lateral projection A small film changer for industrial film (ANGANTYR & OLIN 1973) was used, the series being 1 film/s for 6 seconds, FFD 45 cm, focus 1 0 mm Film Agfa Gevaert D4, no intensifying screens or foils Exposure data 80 kV, 20 mAs, 0 04 s Four vasoactive drugs were administered in connection with angiography tolazoline (Priscolin Ciba, Switzerland) in doses of 0 125 to 0 250 mg, angiotensin (Hypertensin N, Ciba) in doses of 0 0025 to 0 005 µg, norepinephrine, because of its less long-lasting effect preferred to epinephrine, (Norexadrin, Astra, Sweden) in doses of 0 025 to 0 05 µg, and finally vasopressin (Octapressin, Sandoz, Switzerland) in doses of 0 005 to 0 01 IU The drugs, diluted in saline, were injected into the renal, coeliac or hepatic artery 15 to 20 s before angiography, performed with half an hour interval between each examination Tolazoline, having a long-lasting effect, was in all instances used for the last series in each case In all series 0 3 to 0 5 ml (depending on the blood flow rate) of Isopaque Cerebral (Nyco, Norway) was injected by hand

Following angiography, the rats were killed and autopsy was performed At least



Fig 5 Numerous blood filled vessels in DMN induced kidney tumour of epithelial type Hematoxylin-eosin × 160

rats, angiotensin and norepinephrine angiography revealed a few tiny abnormal vessels

Four of the five DMN induced kidney tumours had a mesenchymal, sarcomatous character (EKELUND & JONSSON) The cellularity varied with smaller parts of the tumo[illegible]

[illegible] poorly vascularized with a somewhat richer vascularity in the periphery (Fig 3) Most of the *vessels were* thin-walled, of capillary or venous type, walled by endothelium but no smooth *muscle cells* (Fig 4) A few vessels had the character of small arteries or arterioles with smooth muscle cells in their walls One tumour was dominated by leiomyomatous parts, poorly vascularized

One of the DMN induced tumours was of epithelial type with considerably richer vascularity (Fig 5) The trabecular or tubular tumour formations were surrounded by a rich network *of often* dilated vessels with somewhat swollen endothelium and scattered smooth muscle cells

The transplanted kidney tumours *were localized* beneath the capsule and had the character of anaplastic carcinoma and anaplastic, rather small-cell sarcoma, respectively The *carcinoma tissue* was sparsely supplied with endothelium coated vessels without any *muscle cells, while* the sarcomas contained rather numerous such vessels In both types of *tumour tissue* blood pools of different sizes without any demonstrable vessel walls were found



Fig 3



Fig 4

Fig 3 Peripheral part of DMN-induced kidney tumour of mesenchymal type Poor vascularity towards the centre of the tumour (bottom) somewhat richer in the border region to normal kidney (upward) Hematoxylin-eosin × 100

Fig 4 Endothelium-coated vessel in the same tumour No smooth muscle cells in the vessel wall Hematoxylin-eosin × 375

four sections (5 μ) were prepared from each tumour and stained with hematoxylin-eosin and according to van Gieson

Results

Four of the five renal tumours induced by DMN were poorly vascularized, in two of these angiotensin slightly increased the diagnostic information by demonstrating some more abnormal vessels (Fig 1), while the other drugs were of no value In the remaining 2 cases pharmacoangiography failed to demonstrate any abnormal vessels whatsoever

One DMN-induced tumour contained abundant abnormal vessels. In this case all vasoconstrictors provided a better demonstration of the abnormal vascularity as compared to control angiography. Tolazoline was without effect (Fig 2).

The four kidney tumours induced by intrarenal injection of tumour cells were extremely hypovascular at angiography and located peripherally in the kidneys, control series in all cases only demonstrating avascular expansive lesions In one of these

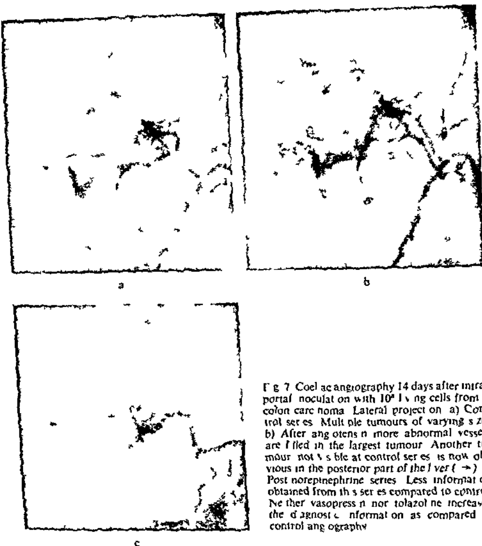


Fig. 7. Coeliac angiography 14 days after intraportal inoculation with 10[illegible] living cells from a colon carcinoma. Lateral projection. a) Control series. Multiple tumours of varying size. b) After angiotensin more abnormal vessels are filled in the largest tumour. Another tumour, not visible at control series, is now obvious in the posterior part of the liver (→). c) Post norepinephrine series. Less information obtained from this series compared to control. Neither vasopressin nor tolazoline increased the diagnostic information as compared to control angiography.

sin gave *some* more information in 5 of 8 rats. Tolazoline gave increased diagnostic information as compared to control series only in 1/8 animals. Thus angiotensin was superior to the other drugs in demonstrating abnormality (Figs 6, 7). In one case, however, vasoconstrictors failed to demonstrate tumours that were obvious at control angiography, the doses being higher than otherwise employed (Fig. 8).

The liver tumours had the same appearance of anaplastic carcinomas as the kidney transplants. Tumour emboli were often seen in dilated portal vessels, sometimes with beginning invasion of adjacent liver tissue. Some of the larger liver tumours had a central hemorrhagic necrosis. The vital tumour tissue was generally rather poorly vascularized although variations in the number of vessels were observed. The vessel

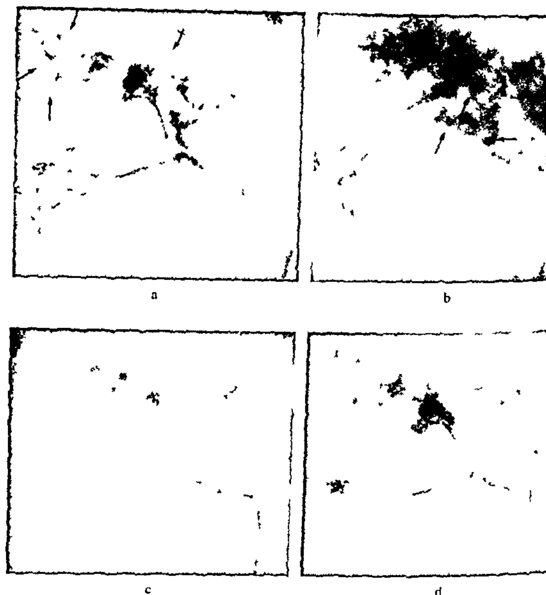


Fig 6 Coeliac angiography 10 days after intraportal injection of 10⁶ living cells from a colon c
liver with pooling
ur (↔) b) Follo
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series

Liver tumours induced by intraportal injection of tumour cells were in all 10 cas multiple, often with an avascular center and a hypervascularized rim at angiograph Pooling of contrast medium was seen in 6 cases The size of the tumours varied b tween 2 and 15 mm in diameter In 9 cases angiotensin gave increased diagnost information as more abnormal vessels were demonstrated the tumour was bette demarcated, and often an increased number of tumours were revealed Norepine phrine in the same way increased the diagnostic information in 6 cases and vasopres

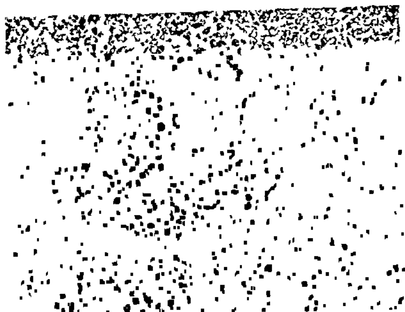


Fig 9 Anaplastic carcinoma in the liver after intraportal injection of tumour cells Several blood pools of different sizes without any endothelial coating One small endothelium-coated vessel terminates in a blood pool (right) Hematoxylin-eosin × 160

presented the results from experiments on the vasoconstrictive effect of adrenalin on the dog's kidney and discussed the possibility of better demonstration of tumour vessels by means of pharmacoangiography BRODY & FISCHER (1964) found in dogs that catecholamines constricted smaller vessels than was evident from the results of ABRAMS *et coll*, suggesting that the discrepancy in site of action might be dose-related ELKIN & MENG (1965, 1966), also in dog experiments, found that angiotensin, regardless of the dose used, constricted only peripheral vessels, while epinephrine constricted also major *renal*

LINDVALL (1967),

(1970) *in clinical* applications reported improved diagnostic information in renal carcinomas following angiography with epinephrine This effect is based on the primitive character of newly formed tumour vessels, which lack contractile elements (BILLING & LINDGREN 1944, LAGERGREN *et coll* 1960, 1961), thus being unable to respond to a vasoactive stimulus While normal vessels contract after

animations

Earl, reports, thus being promising, were followed by some criticism, when benign and malignant renal lesions were diagnosed incorrectly (KAHN & WISE 1967, CARO et coll 1969, ROSS & BALTAXE 1971) Based upon the suggestion made by ELKIN &

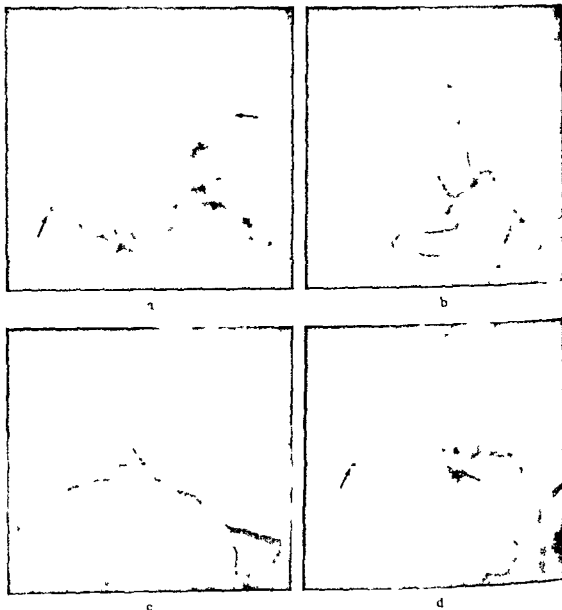


Fig 8 a) Control coeliac angiography Two small tumours (→) b) After 0 005 µg of angiotensin hepatic arteries constricted and no contrast medium reaches the tumours c) The hepatic arteries even more constricted after 0 05 µg of norepinephrine d) Post tolazoline angiography One of the tumours is faintly visible (→)

walls had the same character as in the kidney tumours without any smooth muscle cells, although sometimes ordinary vessels could be observed These tumours also contained rather numerous blood pools of different sizes without any endothelial coating and sometimes the vessels seemed to terminate in such pools (Fig 9)

Discussion

Pharmacoangiography is a debated but widely used method to improve the differential diagnosis between benign and malignant lesions ABRAMS et coll (1962)

which increased the diagnostic accuracy at angiography as well as at the dye-dilution measurement The authors suggested the use of angiotensin to improve the diagnostic information in cases of hemangiomas, small arteriovenous fistulas and tumours in man

Experimental tumours provide an excellent model for such comparative pharmacoangiographic investigations Previously a technique for selective catheterization of most arteries in the rat was developed (EKELUND & OLIN) and this technique has proved suitable for angiography of various experimental tumours (EKELUND & JONSSON, EKELUND et coll 1972 b, EKELUND et coll 1974)

It was surprising to find that the *transplanted kidney* tumours appeared extremely hypovascular at angiography, while microscopy demonstrated a fairly large number of vessels A possible explanation for this seems to be that these peripherally located tumours were not fed from the renal arteries

On the basis of the present results it may be concluded that to demonstrate *poorly* vascularized tumours, vasoconstrictors should be preferred to *vasodilators This is also reasonable from a logic* point of view as tumour vessels do not react on vaso-*active stimuli*, the greatest amount of contrast medium directed into these vessels *should* be achieved after constriction of normal vessels surrounding the lesion *The effect* of various vasoconstrictors was also found to be dose-dependent which *influences* the diagnostic information achieved at pharmacoangiography This is *evident* from one of the cases where too high a dose prevented demonstration of the *liver* tumours Angiotensin turned out to give most diagnostic information in these experiments with renal and hepatic tumours, which corresponds to clinical experiences of this drug

SUMMARY

Pharmacoangiography with four vasoactive drugs was performed in experimental renal and hepatic tumours *in rats in order* to compare their ability to demonstrate tumour vascul-arity Thre[illegible]
dilat[illegible]
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nost[illegible] primitive character of tumour vessels, being unable to react upon a vasoactive *stimulus Angiotensin turned out to* be the superior drug which corresponds to clinical experiences of this drug

ZUSAMMENFASSUNG

Pharmakoang[illegible]
und Lebertum[illegible]
Tumor-Vasku[illegible]
Vasopressin, u[illegible]
toren die best[illegible] Effektunterschiede zwischen diesen gelegentlich geringfügig und wahrscheinlich *Dosisabhängig sind* Der diagnostische Effekt be-

MENG (1966), that angiotensin acts more peripherally on renal vessels than epinephrine, the former drug was employed in angiography of renal masses with good results (EKELUND et coll. 1972 c). A survey on pharmacoangiography of the kidney is given by EKELUND (1973).

Angiotensin has since been used in other vascular regions, e.g. the liver, pancreas and extremities, the diagnostic information being improved in about 70 per cent of cases (EKELUND & LUNDERQUIST 1974).

Epinephrine has also been used in coeliac and superior mesenteric angiography to improve the diagnosis of malignant lesions (BOIJSEN & REDMAN 1967, KAHN et coll. 1967, KAUDE & WIRTANEN 1970).

Vasopressin has mostly been used in the treatment of gastrointestinal hemorrhage (BAUM & NUSBAUM 1971, RÖSCH et coll. 1972). CARLSSON & ERIKSON (1970) however, employed this drug in nephroangiography and found that vasopressin contracted the arteries, did not change the circulation time and increased the retrograde flow of contrast medium, indicating some decrease in the renal blood flow. Tumour vessels were not affected by the drug. Using a dye dilution technique GÖTHLIN (1976) in humans found an initial decrease in renal blood flow within the first 20 seconds and a compensatory increase in flow 3 minutes after arterial injection of 0.5 IU vasopressin. As to the hepatic arterial system it has been shown that vasopressin initially induces a decrease in hepatic blood flow, soon followed by increased flow, presumably due to a compensatory vasodilatory response (CONN et coll. 1973). In the present experiments the vasoconstrictive effect of the drug was achieved by performing angiography 15 to 20 seconds following the intraarterial vasopressin injection.

Thus, vasoconstrictors have been widely used in connection with angiography to enhance demonstration of tumour vessels. Vasodilators, on the other hand, have been used most often to enhance arterial portography (BOIJSEN & REDMAN 1966, REDMAN et coll. 1969). However, KAHN & CALLOW (1965) tried tolazoline in order to improve the diagnostic information in femoral, coeliac and bronchial angiography, and recently HAWKINS (1973) and HAWKINS & HUDSON (1974) have advocated the use of this drug to demonstrate poorly vascularized visceral, bone and soft tissue tumours.

It is thus obvious that vasoconstrictors as well as vasodilators have their advocates in order to improve the angiographic diagnosis of malignant lesions. CARLSSON & ERIKSON compared vasopressin and bradykinin at nephroangiography, but found no effect on tumour vessels. MACGREGOR & HAWKINS (1973) reported tolazoline to be superior to epinephrine in demonstrating pancreatic arteries. With these exceptions no clinical comparison of the effect of vasoactive drugs on tumour vascularity in the individual case seems to have been undertaken. EKELUND et coll. (1972 a) examined the effect of various vasoactive drugs on arteriovenous fistulas in rabbit kidneys in connection with angiography and blood flow measurements with a dye-dilution technique. Among the drugs tested were angiotensin, norepinephrine, phentolamin (Regitin, Ciba, Switzerland) and vasopressin. Angiotensin proved to be the drug

which increased the diagnostic accuracy at angiography as well as at the dye dilution measurement The authors suggested the use of angiotensin to improve the diagnostic information in cases of hemangiomas, small arteriovenous fistulas and tumours in man

Experimental tumours provide an excellent model for such comparative pharmacoangiographic investigations Previously a technique for selective catheterization of most arteries in the rat was developed (EKELUND & OLIN) and this technique has proved suitable for angiography of various experimental tumours (EKELUND & JONSSON, EKELUND et coll 1972 b, EKELUND et coll 1974)

It was surprising to find that the transplanted kidney tumours appeared extremely hypovascular at angiography, while microscopy demonstrated a fairly large number of vessels *A possible explanation for this seems to be that these* peripherally located tumours were not fed from the renal arteries

On the basis of the present results it may be concluded that to demonstrate poorly vascularized tumours, vasoconstrictors should be preferred to vasodilators This is also reasonable from a logic point of view as tumour vessels do not react on vasoactive stimuli, the greatest amount of contrast medium directed into these vessels should be achieved after constriction of normal vessels surrounding the lesion The effect of various vasoconstrictors was also found to be dose-dependent which influences the diagnostic information achieved at pharmacoangiography This is evident from one of the cases where too high a dose prevented demonstration of the liver tumours Angiotensin turned out to give most diagnostic information in these experiments with renal and hepatic tumours, which corresponds to clinical experiences of this drug

SUMMARY

Pharmacoangiography with four vasoactive drugs was performed in experimental renal and hepatic tumours in rats in order to compare their ability to demonstrate tumour vascularity Three vasoconstrictors, angiotensin, norepinephrine and vasopressin, and one vasodilator, tolazoline, were tested, vasoconstrictors giving most diagnostic information and the difference in effect among these sometimes being small and probably dose-related This diagnostic effect is based upon the primitive character of tumour vessels, being unable to react upon a vasoactive stimulus Angiotensin turned out to be the superior drug which corresponds to clinical experiences of this drug

ZUSAMMENFASSUNG

Pharmakoangiographie mit vier vasoaktiven Substanzen wurde bei experimentellen Nieren- und Lebertumoren der Ratte vorgenommen, um deren Brauchbarkeit zu vergleichen, die Tumor-Vaskularität nachzuweisen Drei Vasokonstriktoren, Angiotensin, Norepinephrin, Vasopressin, und ein Vasodilator, Tolazolin, wurden getestet; dabei gaben die Vasokonstriktoren die beste diagnostische Information, wobei Effektunterschiede zwischen diesen gelegentlich geringfügig und wahrscheinlich Dosisabhängig sind Der diagnostische Effekt be-

ruht auf dem primitiven Charakter der Tumorgefasse, die nicht auf einen vasoaktiven Stimulus zu reagieren vermogen Angiotensin erwies sich als die beste Substanz, was den klinischen Erfahrungen entspricht

RÉSUMÉ

Les auteurs ont fait une étude pharmaco-angiographique de 4 agents vaso-actifs sur des tumeurs expérimentales rénales et hépatiques du rat pour comparer leur aptitude a mettre en évidence la vascularisation tumorale Trois vaso-constricteurs, angiotensine, norepinephrine et vasopressine, et un vasodilatateur, tolazoline, ont été étudies, les vasoconstricteurs donnent plus d'information diagnostique et la différence d'effet entre eux est parfois petite et probablement liée à la dose Cet effet diagnostique est basé sur le caractère primitif des vaisseaux tumoraux qui sont incapables de réagir a un stimulus vasoactif L'angiotensine s'est révélée etre le meilleur moyen pharmacologique ce qui correspond aux resultats de l'experimentation clinique de cet agent

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ANGIOGRAPHY IN MALIGNANT AND CHRONIC INFLAMMATORY LESIONS OF THE GALLBLADDER

JAN GÖTHLIN and HOLGER PETTERSSON

Since 1967 several reports have appeared, claiming celiac and hepatic angiography to be an accurate method to demonstrate carcinoma of the gallbladder (ABRAMS et coll 1970, CHUDACEK 1968, COULOMB et coll 1974, DEUTSCH 1967, KIDO et coll 1974, PETTERSSON 1974, REUTER et coll 1971, RÖSCH et coll 1969, SATO et coll 1969, SPRAYREGEN & MESSINGER 1972, WENZ 1967) However, with few exceptions (SATO et coll, KIDO et coll) the materials analyzed have been small Little attention has been paid to the possibilities of differentiating between malignant and inflammatory lesions The combined material of gallbladder carcinomas from two university hospitals has therefore been analyzed and compared with a similar number of inflammatory lesions

Material and Methods Angiography of the superior mesenteric and celiac or hepatic arteries has been performed in 18 patients with gallbladder carcinoma and in 17 with cholecystitis All diagnoses have been confirmed microscopically at operation or autopsy

All malignant lesions were adenocarcinomas The whole gallbladder was involved in 15 patients, in two cases the tumour was limited to the fundus of the gallbladder

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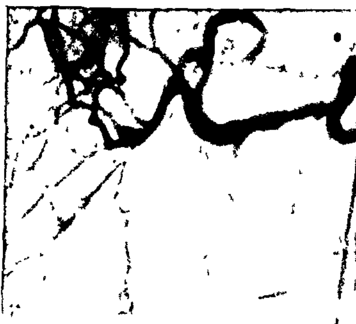


Fig. 1. Encasement of common hepatic artery. The gastroduodenal artery not filled due to reversed blood flow from the superior mesenteric artery because of the stenosis of the hepatic artery. Encasement also of the cystic artery with branches.

Table 1

*Angiographic findings in the 35 patients. * denotes that only 15 patients could be estimated as the gallbladder region in the remaining 3 patients was fully involved by carcinoma, and the gallbladder itself thus not possible to identify*

Microscopy	Carcinoma	Cholecystitis
Number of patients	18	17
Diameter of the cystic artery (mm)	1.0–3.5 (mean 2.1)	1.0–3.0 (mean 2.0)
Interruption or irregularity of the lumen of the cystic artery or its branches	18/18	10/17
Accumulation of contrast medium within tumour or wall of gallbladder	16/18	13/17
Prominent veins of the gallbladder	11/15*	12/17
Irregular wall of the gallbladder 2 mm thick	12/15*	9/17
Dilated gallbladder	4/15*	6/17
Displacement of		
hepatic artery	5/18	1/17
gastroduodenal artery	4/18	2/17
superior mesenteric artery	1/18	0
Encasement of		
hepatic artery	12/18	0
gastroduodenal artery	6/18	0
duodenal and pancreaticoduodenal arteries	8/18	0
portal vein	6/18	0
Early filling of hepatic vein	0	0



Fig 2 Encasement of the cystic artery with

and in one to the fundus and part of the corpus In only two *patients no metastatic or local* spread could be demonstrated at operation

In the cholecystitis group no acute lesions were included The patients *were often examined* because of diffuse pain in the lower abdomen, possibly resulting from gall-*bladder or pancreatic* disease

Results

As is evident from Table 1, there was no *difference* in mean diameter of the cystic artery in the two groups of patients.

In all cases of carcinoma *irregularities* and abrupt interruption of the cystic artery or its branches was demonstrable *In 5 patients* the changes involved the whole cystic artery (Figs 1, 2) in the remaining *13 only* main branches or secondary branches of the cystic artery (Fig 3 a) This *limited engagement* of arteries was confirmed also in patients where microscopy revealed invasion of the whole gallbladder

In most *patients wide* veins, accumulation of contrast medium in the tumour (Fig 3 b) and *irregular thickening* of the wall of the gallbladder (Fig 4) were present



a



b

ery accumulation of contrast me
b) Marked accumulation of con
Operation proved the carcinoma

The wall was considered abnormal if exceeding 2 mm in thickness Encasement of arteries and veins in the vicinity of the gallbladder was common (Fig 1), in order of diminishing frequency affecting the hepatic artery followed by the gastroduodenal and duodenal arteries Encasement of the veins was less common Displacement of other vessels was uncommon and was demonstrable in advanced states of disease only

In chronic cholecystitis (Table 1) irregularities and obstructions of the cystic artery and its branches occurred in only about 60 per cent of the patients and the changes were less severe than in the cases of carcinoma When present, they existed along the whole course of the artery and its branches (Figs 5, 6) In 3 patients,



Fig 4



Fig 5

Fig 4 Irregular thickening of the wall of the gallbladder Operation revealed malignant infiltration of the whole bladder

Fig 5 Dilatation of gallbladder with wide main stem of the cystic artery and branches Microscopy chronic cholecystitis

... only the peripheral parts of the arterial branches were engaged (Fig 7 a) ... bladder ...

of the gallbladder was common Accumulation of contrast medium ... of the gallbladder (Fig 7 b) was evident in 4 cases, in 2 of them in the liver hilum Displacement of the gastroduodenal artery occurred in 2 patients, in one of them also of the portal vein Encasement of vessels outside the gallbladder bed never occurred Omental vessels were often fixed to the vicinity of the gallbladder

Discussion

A survey of the literature reveals 81 cases of carcinoma of the gallbladder examined angiographically (Table 2)

Dilatation of the cystic artery is frequently reported without statement of the normal range of variation of the cystic artery However, LUNDERQUIST (1967) has found the width of the cystic artery to be from less than 1 mm up to 2 mm In the present material only 6 of the cystic arteries exceeded 2 mm and no one exceeded 3 5 mm

Table 2

Survey of the literature Reported findings at celiac, hepatic and superior mesenteric angiography in carcinoma of the gallbladder

	Authors*										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Number of cases	6	5	4	5	25	3	5	7	16	5	18
Dilatation of the cystic artery	6		3	2	17	2	2	7		3	6
Irregularity or interruption of the cystic artery and its branches	6	2	3	2	16	2	5	7	12	1	18
Displacement of the cystic artery					8					2	
Neovascularity	6		3			2	5	7	7	2	
Hypervascularity of the gallbladder					20						
Accumulation of contrast medium within tumour	6	2	4	5	16	2	5		13	4	16
Prominent gallbladder veins			2	1						4	11
Thick, irregular wall of the gallbladder	6			5			0	0	9		12
Dilatation of the gallbladder	1										4
Displacement of the gastroduodenal artery		2			10			2			4
Encasement of hepatic artery (liver metast)		2	4	1	12			5		2	12
gastroduod artery		2								3	6
pancr duod arteries										3	8
portal vein		1	1					2		3	6
sup mes vein										2	0
splenic vein										3	0
Early filling of hepatic vein										2	0
No abnormality						1			1		0

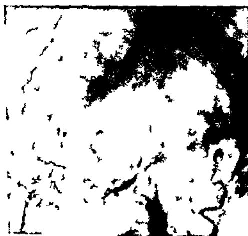
* I ABRAMS et coll (1970), II CHUDACEK (1968), III COULOMB et coll (1974), IV DEUTSCH (1967), V KIDO et coll (1974), VI PETTERSSON (1974), VII REUTER et coll (1971) VIII ROSCH et coll (1969), IX SATO et coll (1969), X SPRAYREGEN & MESSINGER (1972), XI Present series



Fig 6 Small gallbladder with thin irregular cystic artery and branches Microscopy chronic cholecystitis



a



b

Fig 7 Chronic cholecystitis a) Irregular peripheral branches of the cystic artery b) Parenchymatous phase Irregular thickening of the wall of the gallbladder with widened veins and perivesical accumulation of contrast medium

in diameter These may have been slightly dilated Widening of the cystic artery is probably not a reliable sign of disease of the gallbladder if not very marked

Irregular and interrupted arteries accumulation of contrast medium in the tumour and neovascularity are commonly reported and more frequent and more severe in carcinoma than in inflammatory disease

Other findings reported as an irregular thickening of the wall of the gallbladder (ABRAMS et coll) with prominent veins (COULOMB et coll DEUTSCH WENZ) existed also in the present material however early filling of hepatic veins was not observed

which may be explained by less vascularized or less advanced carcinomas without hepatic spread in the patients of the present series. Large veins draining the gallbladder region were found in some patients.

Encasement of arteries and veins outside the gallbladder indicates extrafocal extension of tumour or regional metastases from the carcinoma (SPRAYREGEN & MESSINGER). In advanced cases the site of the primary lesion may be difficult to identify. These findings are in accordance with those in the present series.

No abnormalities have been reported in 3 patients with gallbladder carcinoma (CHUDACEK, PETTERSSON, SATO et coll.). In one of them it may be explained by the lapse of a time interval of more than one year between the angiography and the substantiation of the diagnosis of carcinoma.

In cases of uncomplicated cholelithiasis no angiographic abnormalities other than stretched arteries due to the dilatation of the gallbladder have been reported (RÖSCH et coll.). Widening of the cystic artery with tortuous branches, 'blush', thickening of the gallbladder wall and tortuous gallbladder veins were described in subacute cholecystitis by RÖSCH et coll. In cases of chronic and advanced cholecystitis a thin cystic artery, if visible at all, was reported by DEUTSCH, RÖSCH et coll. and SATO et coll. Microangiography (DE SOUSA 1972) of 20 cholecystitic gallbladder specimens revealed no vascular abnormalities in acute cholecystitis. In chronic disease, however, tortuosity, irregular caliber changes and obstruction of the cystic artery as well as newly formed vessels were present.

Contrary to the reports mentioned, the cystic artery could always be identified in the present material, possibly on account of differences in the patient material or in the angiographic technique. Direct magnification angiography certainly improved the diagnostic information in some of the present patients.

Dilatation of the gallbladder may be caused by either tumour or calculi but was more commonly due to calculi in this material.

Abnormalities of the cystic artery were common and more marked in malignant lesions and differences in the distribution of the changes also appeared but enabled a differential diagnosis only in some cases. Accumulation of contrast medium to the wall of the gallbladder was common in both groups but only in carcinomas appeared as fairly well circumscribed regions with a diameter of 1 to 2 cm. Thickening of the wall of the gallbladder and prominent veins were evident in both groups without distinct differences.

In malignant lesions with vast spread, including involvement of vessels outside the gallbladder itself, the diagnosis is certain. Mere displacement of vessels is not conclusive, as it occurred in both groups.

It may be concluded that in advanced cases of malignant disease and in those with small, localized tumours in the wall of the gallbladder the angiographic diagnosis should be possible. Carcinoma of the gallbladder with small or moderate angiographic abnormalities cannot with certainty be distinguished from chronic inflammatory disease (compare Figs. 2 and 7 a, Figs. 4 and 7 b). When marked ab-

normalities of the gallbladder are demonstrated at angiography, cholecystectomy is to be recommended as carcinoma of the gallbladder cannot be excluded

SUMMARY

Angiographic findings in 18 patients with carcinoma of the gallbladder and 17 with cholecystitis indicate that similar abnormalities may appear in both lesions Irregularities and obstruction of arteries were more common in malignant disease and somewhat more severe Accumulation of contrast medium and prominent veins occurred in both groups Displacement of adjacent vessels was more common in malignant disease As chronic inflammatory lesions cannot with certainty be differentiated angiographically from malignant disease, cholecystectomy is recommended when the abnormalities described are demonstrated

ZUSAMMENFASSUNG

Die angiographischen Befunde bei 18 Patienten mit Karzinomen der Gallenblase und 17 Patienten mit Cholezystitis deuten darauf hin dass ahnliche Abnormalitaten in beiden Fallen auftreten konnen Irregularitaten und Obstruktionen der Arterien waren bei der malignen Erkrankung am gewohnlichsten und etwas mehr ausgepragt Eine Akkumulation von Kontrastmittel und hervortretende Venen traten bei beiden Gruppen auf Eine Verlagerung der angrenzenden Gefasse war gewohnlicher bei der malignen Erkrankung Da eine chronische inflammatorische Veranderung nicht mit Sicherheit angiographisch von einer malignen Erkrankung abgegrenzt werden kann wird eine Cholezystektomie empfohlen, wenn die beschriebenen Veranderungen gefunden werden

RESUMÉ

Les résultats angiographiques chez 18 malades atteints de cancer de la [illegible]

[illegible] existent dans les deux groupes de malades Les deplacements des vaisseaux voisins sont plus frequents dans le carc[illegible]nome [illegible]

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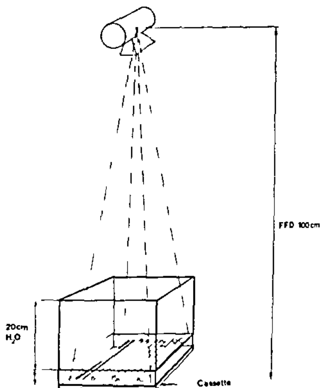


Fig 1 Experimental set up

Material and Methods

Ducts with diameters of 5, 10, 15 and 20 mm were drilled in a homogeneous piece of plexiglass, measuring 5 cm × 10 cm × 25 cm externally Plexiglass balls with diameters of 1, 3, 8, 12 and 18 mm were placed in the ducts, which then were filled with diatrizoate (Urografin) in concentrations of 5, 10, 22 5 and 45 per cent by weight A 20 cm thick layer of water served as a body phantom (Fig 1) Films were exposed with tube potentials of 70, 80, 90, 100, 110, 125 and 150 kV

The exposures were chosen to obtain a homogeneous background density of the films of 1 8 units A three-phase, six-pulse generator was used The nominal tube focus was 1 mm × 1 mm The tube potential was controlled with a penetrameter (ARDRAN & CROOKS 1968) Ilford Rapid R film and CEA universal intensifying screens were used The characteristic density curve for this film is reproduced in Fig 2, which reveals that the gamma value of the film already begins to decrease at values below 1 0 The images were assessed both subjectively and densitometrically An assessment was made of the conditions under which various calculi were most distinctly discernible and of the smallest calculi that could be detected when other parameters varied A Joyce-Loebl Microdensitometer 3 CS with an aperture of 0 15 mm × 0 02 mm was used for the objective assessment The radiographic contrast, C, was defined as $(D_1 - D_2)/(D_1 + D_2)$, where D_1 and D_2, respectively, are the measured numerical values for density behind and adjacent to the calculus being

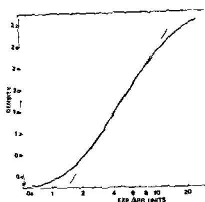


Fig 2 Characteristic curve of Ilford Rapid R film combined with CEA universal intensifying screens

assessed C is therefore a measure of visibility The limit value for C at which the difference in density was clearly discernible to the naked eye was about 0 015

Results

Tube potential of 70 to 80 kV Small calculi—3 mm in diameter—were visible in the narrow ducts at all contrast medium concentrations and became more evident with increasing concentrations (Fig 3) As the diameters of the ducts increased, the ducts were more and more underexposed, especially at higher contrast medium concentrations Thus, at a duct diameter of 20 mm, the 3 mm calculi were just barely discernible with contrast medium 45 per cent (Fig 4) The calculus was most evident in the duct with contrast medium 10 per cent The density behind the 20 mm wide duct for different kV values with the contrast medium 45 per cent appears in Fig 5 At 70 kV the value for the density lies far below the linear part of the density curve (cf Fig 2)

Tube potential of 90 to 110 kV Small calculi—3 mm in diameter—were clearly visible in [illegible]
of C dec[illegible]
kV appro[illegible] in narrow (Fig 3) nor wide ducts (Fig 4) were small calculi visible At a duct diameter of 20 mm and a calculus diameter of 3 mm it was possible to demonstrate a visibility maximum which occurred at about 97 kV with the 22 5 per cent contrast medium and at just above 100 kV with the 45 per cent medium (Fig 4) This was true at the background density selected, i e 1 8 units

Tube potential of 110 to 150 kV The values for C was lower at these tube potentials than at 90 to 100 kV in all cases where calculi could be detected, i e only at the two higher contrast medium concentrations The visibility was similar, and fairly good, for 3 mm calculi in the 5 mm as well as 20 mm ducts at the 22 5 per

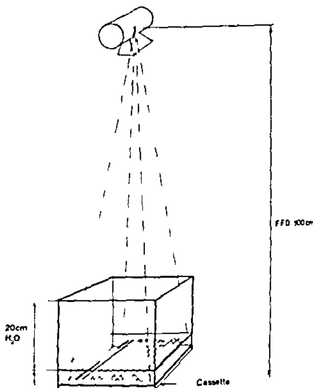


Fig 1 Experimental set up

Material and Methods

Ducts with diameters of 5, 10, 15 and 20 mm were drilled in a homogeneous piece of plexiglass, measuring 5 cm × 10 cm × 25 cm externally Plexiglass balls with diameters of 1, 3, 8, 12 and 18 mm were placed in the ducts, which then were filled with diatrizoate (Urografin) in concentrations of 5, 10, 22 5 and 45 per cent by weight A 20 cm thick layer of water served as a body phantom (Fig 1) Films were exposed with tube potentials of 70, 80, 90, 100, 110, 125 and 150 kV

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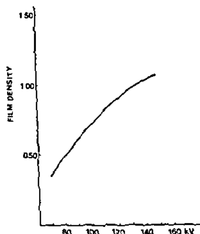


Fig. 5 Film density behind the centre of a 20 mm duct when the background density is 1 8 and the contrast medium concentration in the duct is 45 %

escaped detection at cholangiography However, as most calculi are impossible to palpate during operation, this method was an improvement and since that time operative cholangiography has been employed routinely in connection with gall-bladder operations in many parts of the world A choledochotomy is performed in 30 to 40 per cent of these operations on the basis of the cholangiography, i e demonstrated or possible calculi or widening of the common bile duct to more than 10 mm in diameter Calculus is found in the bile ducts in 51 to 75 per cent of these cases (LINDSKOG 1970, HALL et coll 1973) If these results are generally valid the diagnostic reliability in operative cholangiography is not particularly great, wherefore it is highly important to improve the technique, not least because a common bile duct exploration is a considerably larger operation than an ordinary cholecystectomy

The wider the bile ducts the lower the diagnostic reliability, above all because of the fact that the wide bile ducts will easily be underexposed The most frequent method of avoiding this difficulty to some extent, has been to dilute the contrast medium In a model experiment similar to the present one NISHIZAWA (1968) analysed the possibility of detecting calculi of different sizes in bile ducts of different widths at varying concentrations of the contrast medium at a tube potential of 75 kV He found that the optimum contrast medium concentration was 25 to 50 per cent in bile ducts with a diameter of 5 mm, 6 per cent at 24 mm and 3 per cent for a bile duct width of 32 mm Previously, corresponding but less comprehensive experiments had been performed on the rabbit (ASHMORE et coll) They also used a fixed tube potential of 76 kV In a clinical material, HUR et coll tried to calculate the volume of bile ducts on the basis of their width in order to optimize the dilution procedure They reported a volume of 9 ml for a common bile duct diameter of 10 mm, 20 ml for a diameter of 15 mm and 36 ml for a diameter of 20 mm However, clinically, the possibility of optimizing the dilution of the contrast medium on the basis of the bile duct diameter is obviously limited The diameter is seldom known before the

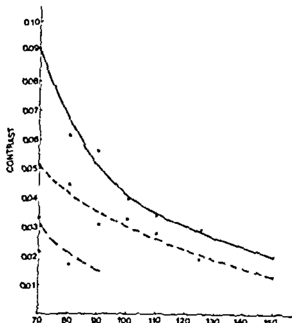


Fig 3

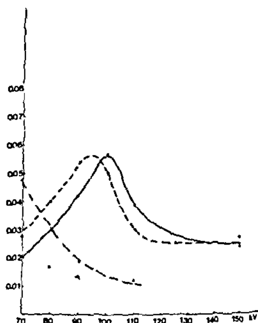


Fig 4

Fig 3 Contrast (C) at a calculus diameter of 3 mm and a duct diameter of 5 mm at different contrast medium concentrations and tube potentials —— 45 % ---- 22 5 % — — 10 % 5 %

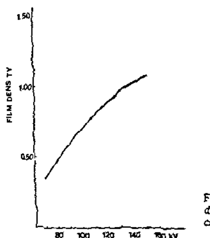
Fig 4 Contrast (C) at a calculus diameter of 3 mm and a duct diameter of 20 mm —— 45 % ---- 22 % — — 10 % 5 %

cent and 45 per cent concentrations (Figs 3, 4) It was not until the tube potential approached values around 110 kV that the film density behind the widest duct amounted to about 0 8 units (Fig 5)

Calculi with a diameter of 1 mm could only be detected in narrow ducts with a high contrast medium concentration and a low tube potential Calculi with diameters of 8, 12 and 18 mm were easy to detect in practically all cases However, in principle, the visibility did not differ from that stated for calculi with a diameter of 3 mm When the contrast medium concentration was high and the tube potential low, small calculi were easy to detect in narrow ducts but difficult to observe in wide ones At 100 kV small calculi were easy to detect in both narrow and wide ducts provided that the contrast medium concentration was high To the naked eye the appearance of a calculus with a diameter of 3 mm in a 20 mm wide duct was the same in a contrast medium with a concentration of 10 per cent at a tube potential of 70 kV as in a 45 per cent contrast medium at 110 kV (Fig 6) This figure also illustrates some of the material on which the present assessments were based

Discussion

Cholangiography during operation was performed for the first time in 1932 by MIRIZZI A more complete investigation of this method was made by HULTÉN (1938), at which time it was already obvious that many calculi in the bile ducts



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They reported a volume of
for a diameter of 15 mm and
the possibility of
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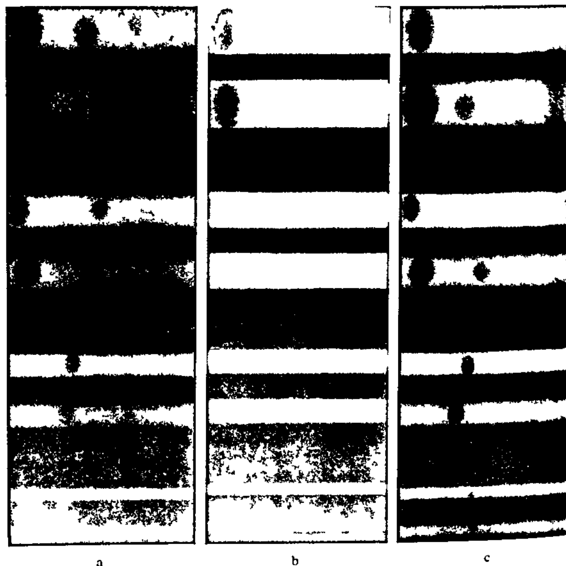


Fig 6 Calculi of a diameter of 1 3 8 12 and 18 mm in 5 10 15 and 20 mm ducts a) The ducts
nd the film is exposed at a tube potential of 70
id 22 5 . respectively In (b) the film exposed
110 kV a calculus with a diameter of 3 mm
(→) has the same appearance to the naked eye as in contrast medium of a concentration of 10°
and a tube potential of 70 kV (→)

operation and may be difficult to assess even during the operation before cholangiography has been performed and optimum exposure of both wide and narrow ducts is not possible on the same film at a tube potential of 70 to 75 kV A low tube potential generally entails longer exposure times and thus greater blur due to motion Lower tube potentials also expose the patient to a higher absorbed dose A higher tube potential entails a smaller total difference in attenuation in the object (HERMS & MOTZKUS 1969), but this can be compensated for by a higher contrast medium concentration (COCCHI 1954) The present results indicate that increasing the tube

potential up to 110 kV produces an equal or better effect with regard to diagnostic reliability than decreasing the contrast medium concentration At higher potentials the loss of contrast caused by secondary radiation becomes increasingly disturbing and makes the diagnosis difficult The reason why the attenuation differences (i e the radiographic contrast) between calculi and the surrounding medium decrease with wide ducts, high contrast medium concentration and low tube potentials, is that the wide ducts are under-exposed due to the limited latitude of the film (Fig 4) This effect can be reduced by increasing the exposure, but then the attenuation in the narrow ducts will be too high for adequate diagnosis Optimum results seem to be gained at a tube potential between 95 and 105 kV and a contrast medium concentration of 45 per cent Under these conditions small calculi in wide ducts can be demonstrated with a higher degree of reliability than at a low potential and more diluted contrast medium It is true that the visibility increases for small calculi in the narrower ducts at lower tube potentials, but it is still quite adequate for diagnostic purposes at 100 to 110 kV On the other hand, it would be clearly unsuitable to use a high tube potential and a low contrast medium concentration because the detection of calculi is then rendered more difficult

The most important result of the present investigation is the demonstration of a visibility maximum for small calculi in wide ducts at around 100 kV with a 45 per cent concentration of the contrast medium (Fig 4), provided that the density of the film used is practical for clinical use Other advantages of this high tube potential as compared to the one that seems to be most common are a greater exposure latitude, a shorter exposure time and the lower radiation dose to the patient Thus, the negative effects of the higher tube potential in the form of increased secondary radiation and reduced radiographic contrast are compensated for by other factors It must be borne in mind, however, that in clinical use the contrast medium is diluted with the bile to a variable degree from case to case depending on the width of the duct and the technical procedure used

SUMMARY

Model cholangiographic experiments were performed in which the relationship between contrast medium concentration, duct diameter, calculus size and tube potential was analysed The same degree of diagnostic reliability was obtained by increasing the tube potential as by diluting the contrast medium A tube potential of 100 to 110 kV and a contrast medium concentration of 45 per cent were found to give the best result if the background density of the film was held constant

ZUSAMMENFASSUNG

Modellexperimente zur Cholangographie wurden vorgenommen bei denen das Verhaltnis zwischen der Kontrastmittelkonzentration, dem Diameter des Gallenganges der Grosse des Calculus und der Rohrenspannung analysiert wurden Derselbe Grad der diagnostischen Zuverlässigkeit wie durch eine Erhohung der Rohrenspannung wurde durch Verdunnung

des Kontrastmittels erhalten Eine Rohrenspannung von 100 bis 110 kV und eine Kontrastmittelkonzentration von 45 Prozent ergaben die besten Ergebnisse wenn die Hintergrundsdichte des Films konstant gehalten wurde

RÉSUMÉ

Les auteurs ont fait une expérimentation cholangiographique sur modele dans laquelle ils ont étudié les relations entre la concentration du moyen de contraste, le diamètre des canaux biliaires, la taille du calcul et le potentiel dans le tube Ils ont obtenu le meme degré de fiabilité diagnostique en augmentant le potentiel dans le tube ou en diluant le moyen de contraste Ils ont constaté qu'un potentiel dans le tube de 100 à 110 kV et une concentration de moyen de contraste de 45% donnent le meilleur résultat si on maintient constante la densité de fond du film

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VIDEODENSITOMETRY IN THE DIAGNOSIS OF AORTIC INCOMPETENCE

U ERIKSON, L BJÖRK, I CULLHED, EBBA ENGHOFF and G RUHN

Thoracic aortography is of fundamental importance for the roentgenologic evaluation of aortic valve disease This method has been used for about twenty years to estimate the degree of valvular dysfunction in both aortic stenosis and incompetence However, the estimation of aortic incompetence by this technique has the disadvantage of being semiquantitative

A videodensitometer (Saab-Scania, Linkoping, Sweden) has been used for the last year (BJÖRK et coll 1974) to assess the function of the left ventricle and the aortic valve The findings in patients with aortic incompetence are reported here as clinical results with this method, such results have not previously been published

Material The material consisted of 20 adult patients with aortic valve disease, 12 with incompetence alone and 8 with combined stenosis and incompetence (Table) They were referred for preoperative evaluation

Using the modified classification of the New York Heart Association (WADE & BISHOP 1962) 2 patients belonged to class I, 5 patients to class II, 7 patients to class III A, 5 patients to class III B and 1 patient to class IV, 9 had been in left ventricular failure, 16 had sinus rhythm and 4 had atrial fibrillation

No patients were in clinical heart failure when catheterized All patients continued to receive the previous dosage of digitalis and diuretics

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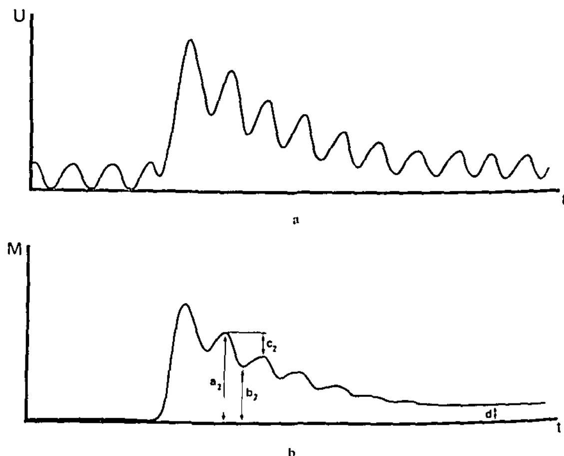


Fig. 1. a) A curve recorded from the densitometer. U represents the voltage and t the time. b) The same curve after subtraction of background. M represents the amount of contrast medium in the left ventricle. d represents mostly contrast medium in the myocardium.

Method and Procedure

All patients were examined in the supine position, in the same laboratory and with the same equipment. The procedure started with hemodynamic analyses including

Table

Distribution of aortic incompetence (AI) and combined incompetence and stenosis (AIAS)

	No. of patients with diagnosis		Patients operated upon	Age (years)	
	AI	AIAS		Mean	Range
Men	7	7	3	54	33 67
Women	5	1	2	52	42–62
Total	12	8	5		

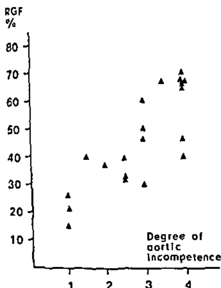


Fig 2 The relation between the regurgitant fraction and the semiquantitative grading of the aortic incompetence

right and left heart catheterization The clinical examination included a work test on an electrically braked bicycle ergometer Among other parameters the left ventricular end diastolic pressure and the stroke volume were measured by standard methods (ENGHOFF 1972) The patients were then turned into the right anterior oblique position and cardioangiography performed

Densitometry was performed before the conventional cardioangiography

In 8 patients the tip of the catheter was placed in the ascending aorta about 2 cm above the valve, in 7 patients in the left ventricle and in 5 a trans-septal catheter was used with the tip in the left atrium near the mitral valve Into the left atrium 20 ml were injected, into the left ventricle 15 ml, and into the aorta 20 ml of Urografin 60% A pressure syringe (Contrac, Contraves AG, Zurich) was used and the injection time was always less than 1 0 s

Videocardioangiography was performed at 60–70 kV, 1–2 mA with an image intensifier (Philips) and a plumbicon The examinations were recorded on a videotape recorder (Oude Delft OD-X40, Delft, Netherlands) and then analyzed by the videovolumeter (BJÖRK et coll) The resulting curves were registered by a direct recorder (Brush 260, Gould Inc , Cleveland, Ohio) together with the ECG Two channels were used in a series in order to obtain more accurate measurements of the curve The dynamic region then became 8 cm instead of 4 cm

The degree of aortic incompetence was calculated from the curves and based upon the heart beats 2, 3 and 4 after the end of the injection of contrast medium (Fig 1) This figure illustrates the curve recorded (a) and the curve obtained after subtraction of the variations of the background attenuation due to heart movements (b)

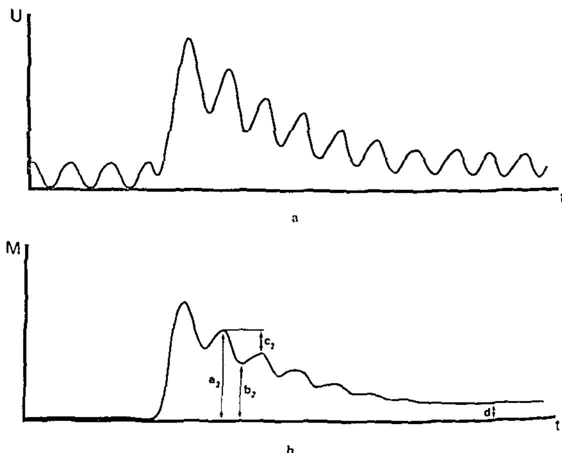


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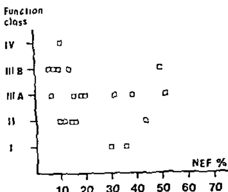


Fig. 5 The functional classification is compared to the net ejection fraction.

The regurgitant fraction calculated from videodensitometry has been compared with the grading of aortic regurgitation (Fig 2) and reveals a relationship between the two methods However, in patients with grade 4 aortic incompetence the regurgitant fractions vary between 40 and 70 per cent of the total stroke volume The functional classification of the patients was also compared to the regurgitant fraction (Fig 3) No correlation was found between the functional classification and the regurgitant fraction and this was the case whether there was a history of left ventricular failure or not

The function classes were related to the gross ejection fraction (Fig 4) Many patients with rather severe symptoms and signs, that is III A had B, had a good pump function of the left ventricle, expressed as a normal gross ejection fraction, i e 50 per cent or more

No obvious relationship existed between the function classes and the net ejection fraction (Fig 5)

The relationship between the gross and the net ejection fractions appears in Fig 6 The majority of the patients who had been in left ventricular failure had low ejection fractions The gross ejection fraction was then compared with the left ventricular end diastolic pressure at rest but only a poor correlation between the two parameters was found (Fig 7)

No correlation was found between the physical working capacity and the net or gross ejection fraction

Discussion

The relationship between the recordings on the videodensitometer and the amount of iodine is almost linear (Björk et coll) The formulas used are based upon the assumption that some part of the contrast medium injected into the aorta passes through the incompetent valve into the left ventricle The amount of iodine in the ventricle is measured in diastole During the following systole the amount will de- This decrease is a function of the total stroke volume in relation to the diastolic : During the following diastole there is again an increase in the amount of due to the aortic regurgitation This increase represents that part of the pre-

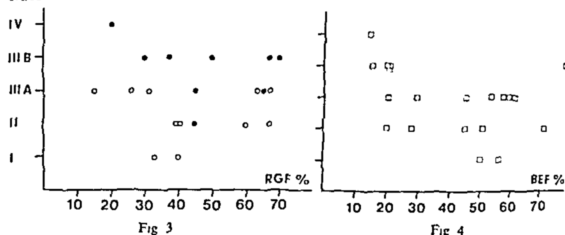


Fig 3

Fig 4

Fig 3 The functional classification is compared to the regurgitant fraction ● represents patients *with a history of left ventricular failure*

Fig 4 The functional classification is compared to the gross ejection fraction (BEF)

The following formulas were used

Gross ejection fraction $\frac{a_n - b_n}{a_n}$ (1)

Net ejection fraction $\frac{c_n}{a_n}$ (2)

Regurgitant fraction $1 - \frac{c_n}{a_n - b_n}$ (3)

n indicates the order of heart beat following the injection of the contrast medium

Conventional angiography was performed with cine technique, 75 frames/s (Arriflex) and with the same equipment as in the densitometry, but with biplane added In all patients 40 ml of Urografin 60 % were injected into the ascending aorta at a rate of 25 ml/s

A four-graded scale according to CULLHED (1964) was used Grade 1 subvalvular contrast leakage Grade 2 contrast medium reflux into the upper half of the ventricle Grade 3 the entire left ventricle filled but only slight concentration of the medium Grade 4 as grade 3 but the same concentration as in the aorta

Results

The gross and net ejection fractions and regurgitation fractions varied within a very limited range and the values in the diagrams are the mean values from heart beat 2, 3 and 4

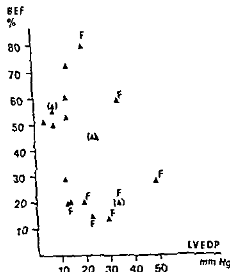


Fig 7 The relation between the gross ejection fraction (BEF) and the end diastolic pressure in mm Hg F means patients with a history of left ventricular failure ( ) means that the pressure is measured in PCV or in the left atrium

The videodensitometric method makes it possible to calculate the net and gross ejection fractions for many consecutive beats The combination of low ejection fraction and high regurgitant fraction may describe more objectively the severity of the heart disease than the subjective assessment of the left ventricular contractility and the aortic incompetence

The functional classification correlated poorly with the function of the left ventricle or that of the aortic valve (Figs 3 to 5) This may be due to the fact that some severely diseased patients both have a low gross ejection fraction and a high regurgitation fraction but in other patients these factors may not be combined

The functional classification refers to the active physical capacity of the patients but the measurements of the left ventricular end diastolic pressure, net and gross ejection fractions, and the function of the aortic valve are made when the patient is at rest

Most patients with a history of left ventricular failure have a gross ejection fraction of lower than 50 per cent and in addition the left ventricular end-diastolic pressure at rest is increased However, it has not been possible to classify the patients in more detail according to the frequency and severity of the left ventricular failure

It is possible that the analysis becomes more complicated in cases with combined aortic and mitral valve incompetence, and tachyarrhythmias

SUMMARY

The videodensitometer has been used in a group of 20 patients with aortic incompetence and incompetence combined with stenosis The method appears effective in the preoperative evaluation of the valvular and ventricular function of the patient It gives objective and

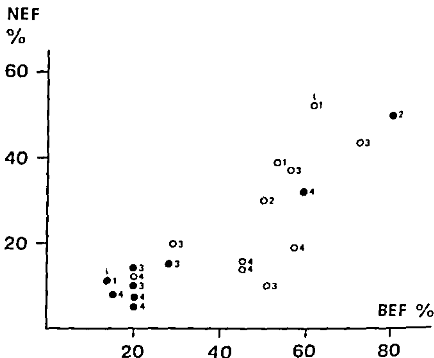


Fig 6 The relation between the net ejection fraction and the gross ejection fraction (BEF) ● represents patients with a history of left ventricular failure The numbers (1–4) represent the degree of aortic incompetence ↓ represents patients who have been operated upon with an aortic valve prosthesis

vious stroke volume which regurgitates into the left ventricle Thus it is possible to calculate from the curves the fraction of regurgitation, i e the fraction of the stroke volume which is regurgitated

Another assumption is that the stroke volume fills the proximal aorta and that the concentration of iodine is about the same in this part of the aorta as in the left ventricle during the previous diastole Judging from the cine films this assumption seems to be nearly correct

In a computer simulated analysis the concentration of the contrast medium in the aorta may vary and this influences the calculations of the net ejection fraction and the regurgitant fraction (GROTH et coll 1975)

When comparing a new method with an older one in a group of patients, it is advantageous if the group is not too homogeneous with regard to the severity of the heart disease The present group includes only a few patients with slight symptoms or signs The majority of the patients belong to function class III A or III B Further, there were only a few cases with minimal aortic regurgitation A positive correlation was found between the densitometric measurement and the subjective evaluation of thoracic aortography It seems probable that the human eye cannot estimate between different degrees of regurgitation with such a precision as is possible with the videodensitometry These results are in accordance with those obtained with continuous dye infusion (ENGHOFF 1972)

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KINEMATIC ANALYSIS OF POSTERIOR SPINAL FUSIONS IN PIGS

T H OLSSON, G SELVIK and S WILLNER

The effect of spinal fusion is difficult to evaluate (UNANDER-SCHARIN 1950, ROLANDER 1966, CHAPCHAL 1974) The important thing is not only if a fusion has been obtained, but also when the fusion is stable Despite several experiments (HOESSLY 1916, HAAS 1936, 1946, ROLANDER), no report has been presented in which the post-operative healing process has been followed continuously or the stability in vivo of a healed fusion has been accurately assessed Animal experiments to elucidate the healing process, utilizing a new roentgen method, are here reported

Material and Methods

The material consisted of 5 pigs The first two were operated at one month and the others at three months of age Posterior fusion was applied to L2–L4 in the first three pigs to L1–L3 in the fourth, and to Th15–L2 in the fifth The spinal processes and the arches were decorticated and the intervertebral joints destroyed in all five pigs As internal fixation, a cerclage around the spinal processes was used on pig 2 and clamps between the neural arches on pigs 3, 4 and 5 Tantalum indicators (0 8 mm in diameter, ARONSON et coll 1974) were inserted into the posterior elements of the vertebrae operated upon, and into the two adjacent segments cranially and caudally,

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probably more accurate information of the regurgitation fraction and the ejection fraction than the commonly used semiquantitative methods The method is simple to use and needs no technical changes in the roentgen equipment

ZUSAMMENFASSUNG

Das Fernsehdensitometer wurde bei einer Gruppe von 20 Patienten mit einer Aorten Insuffizienz und einer Insuffizienz kombiniert mit einer Stenose verwendet Die Methode erscheint effektiv bei der präoperativen Beurteilung der Klappen und Ventrikel Funktion des Patienten zu sein Sie gibt objektive und wahrscheinlich genauere Informationen der regurgitierenden Fraktion und der ausstromenden Fraktion als die allgemein verwendeten semiquantitativen Methoden Die Methode ist in ihrer Anwendung einfach und bedarf keiner technischen Veränderungen in der Rontgenausrustung

RÉSUMÉ

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KINEMATIC ANALYSIS OF POSTERIOR SPINAL FUSIONS IN PIGS

T H OLSSON, G SELVIK and S WILLNER

The effect of spinal fusion is difficult to evaluate (UNANDER-SCHARIN 1950, ROLANDER 1966, CHAPCHAL 1974) The important thing is not only if a fusion has been obtained, but also when the fusion is stable Despite several experiments (HOESSLY 1916, HAAS 1936, 1946, ROLANDER), no report has been presented in which the post-operative healing process has been followed continuously or the stability in vivo of a healed fusion has been accurately assessed Animal experiments to elucidate the healing process, utilizing a new roentgen method, are here reported

Material and Methods

The material consisted of 5 pigs The first two were operated at one month and the others at three months of age Posterior fusion was applied to L2–L4 in the first three pigs, to L1–L3 in the fourth, and to Th15–L2 in the fifth The spinal processes and the arches were decorticated and the intervertebral joints destroyed in all five pigs As internal fixation, a cerclage around the spinal processes was used on pig 2 and clamps between the neural arches on pigs 3, 4 and 5 Tantalum indicators (0 8 mm in diameter, ARONSON et coll 1974) were inserted into the posterior elements of the vertebrae operated upon, and into the two adjacent segments cranially and caudally,

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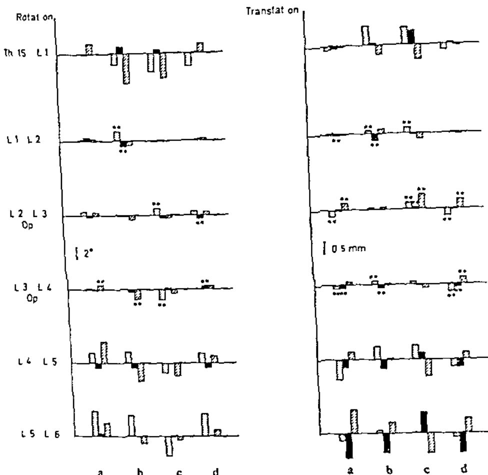


Fig 1 Pig 1 133 days after operation Graphic representation of the final in vivo examination of the first pig performed 133 days postoperatively with a bending moment of 4 5 Nm The Eulerian rotations and the translations for each segment
by the staples Stippled staples stand f
motions related to the y axis and str
of the fused vertebrae represent mot
highly significant motions (p < 0 001
right c Flexion d – Extension

double-evaluations the contribution of the measurement errors to the total mean error of rigid body fitting defined by SELVIK, was computed

The bony union between the operated segments was, as a final step, inspected macroscopically, following removal of the soft tissues

Results

The mean values of the mean error of rigid body fitting for each segment of the pigs appearing in Figs 1 to 6 are given in Table 1 These values range between 18 and

respectively The operations and the roentgen examinations were performed during anaesthesia (droperidolum, Dridol, Leo, and ketaminehydrochloride, Ketalar, Parke Davis)

The first two pigs were examined postoperatively at intervals during four and two months, respectively, whereas the three other animals were examined only on one occasion in vivo, the third pig three months after the operation and the others 2½ months postoperatively A few days after the last in vivo examination, all spines were examined post mortem as specimens, the ribs, the pelvis and the viscera being removed

The examinations were performed with the roentgen stereophotogrammetric method described by SELVIK (1974) and previously utilized by OLIN et coll (1976) Thus, a film was simultaneously exposed with two roentgen tubes at a distance from each other of 70 cm, and with an FFD of 120 cm A calibration cage (model 1 B, SELVIK) was first exposed and then the animal on the same film, without the cassette or the tubes being moved between the two exposures From exact measurements on the film of the indicators in the calibration cage and the animal, three-dimensional coordinates of the indicators in the animal were calculated by data-processing The mutual displacements of the indicators—and the segments in which they were placed—were then calculated by another computer program

The pigs were examined prone at rest and during provoked lateral bendings to both sides as well as extension and flexion Two erect supports were placed beside the animal cranially and caudally to the spinal segments to be analysed A belt around the body of the pig in the middle of the operated area was connected to a weight by a string running over a wheel at the side of the table Thus the animal could be subjected to various bending moments Extension and flexion were achieved in the same way, the pigs lying on their sides The examinations of the specimens were performed by the same method, the only differences were that the specimens were placed in a calibration cage in which a hole for the string was drilled in the lateral wall (model 1 A, SELVIK), and that industrial film was used

The bending moments were calculated by using the mechanical law for a simple beam (NASH 1957)

$$\frac{F \cdot L}{4}$$

where F is the force applied to the middle of the beam, and L is the distance between the supports The length and force are measured in meters and newtons, respectively one newton being the force required to impart an acceleration of 1 m/s² to a mass of 1 kg

The movements of each segment were then calculated by the method of Euler, reviewed by SELVIK, i e the rotations and translations about and along the three axes in space (see Fig 2, OLIN et coll 1976), as well as the total rotation of each segment relative to a reference segment, were computed

The precision of the method was estimated by double-evaluations of four films from a small pig (No 2), a big pig (No 5), and a specimen (No 5) From the same

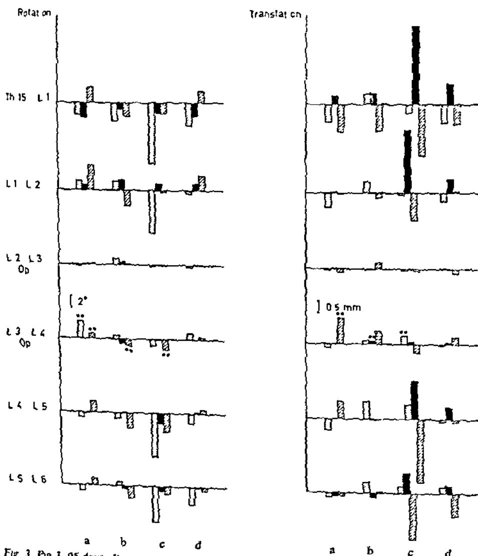


Fig 3 Pig 3 95 days after operation Graphic representation of the in vivo examination of pig 3, performed 95 days postoperatively with a bending moment of 10 Nm For further explanation see Fig 1

the table contains the standard errors s_{rot} for the total rotation angle In each double evaluation 3 segment pairs were included Thus, the standard errors were determined with 4 × 3 = 12 degrees of freedom Assuming a Gaussian distribution of the errors, the measured values that are significantly different from zero ($p < 0.01$) can then be calculated from the Student's t test ($t = 3.055$)

The gradually developing rigidity between the segments of the first pig appears in Figs 7, 8 The curves stand for the total rotation angles of the segments in relation

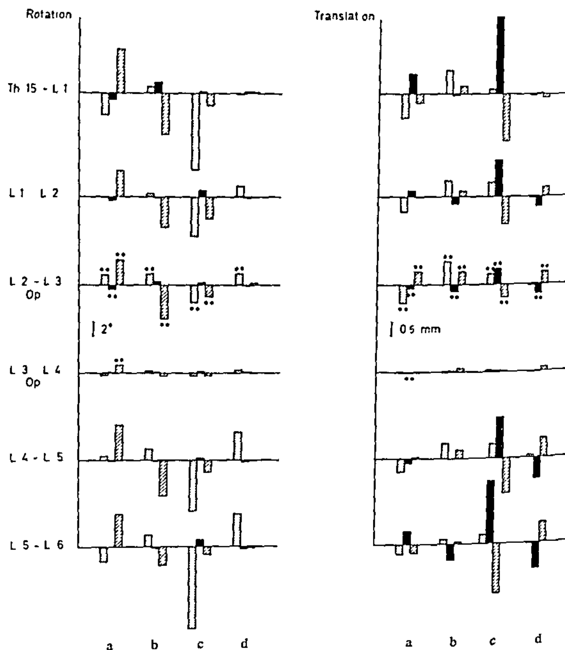


Fig 2 Pig 2 84 days after operation Graphic representation of the final in vivo examination of pig 2, performed 84 days postoperatively with a bending moment of 4 5 Nm For further explanation see Fig 1

123 μm in vivo, whereas the errors post mortem vary between 15 and 85 μm The contribution of measurement errors, as calculated from the precision test, also appears in Table 1

The results of the precision test appear in Table 2, where the standard errors s_ϕ, s_ψ and s_θ for the Eulerian rotational angles ϕ, ψ and θ about the x-, y- and z-axes and the same errors s_x, s_y and s_z for the translations along these axes are given In addition,

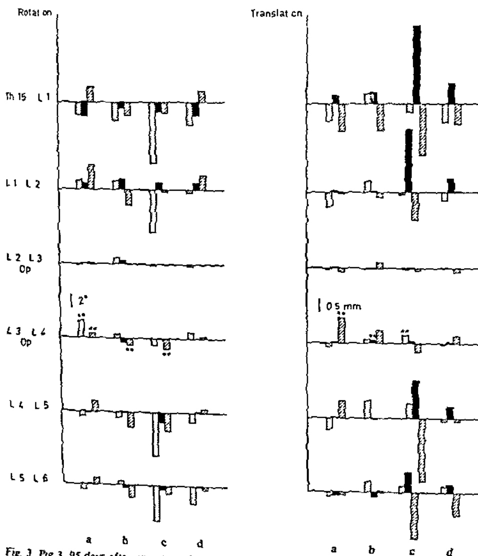


Fig. 3 Pig 3 95 days after operation Graphic representation of the in vivo examination of pig 3 performed 95 days postoperatively with a bending *moment of 10* Nm *For further explanation see Fig 1*

the table contains the standard errors s_{tot} *for the total* rotation angle In each double evaluation 3 segment pairs were included Thus, the standard errors were determined with $4 \times 3 = 12$ degrees *of* freedom Assuming a Gaussian distribution of the *errors*, the measured values *that are significantly* different from zero ($p < 0.01$) can then be calculated from the Student s *t test* ($t = 3.055$)

The gradually developing *rigidity* between the segments of the first pig appears in Figs 7, 8 The curves stand *for the total* rotation angles of the segments in relation

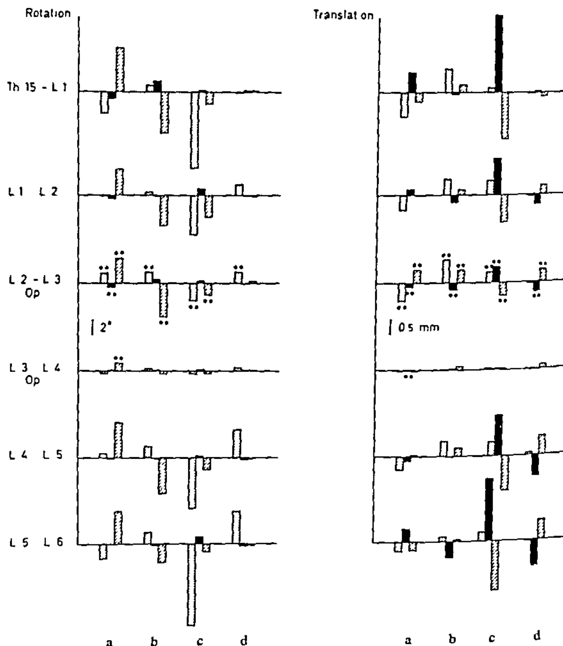


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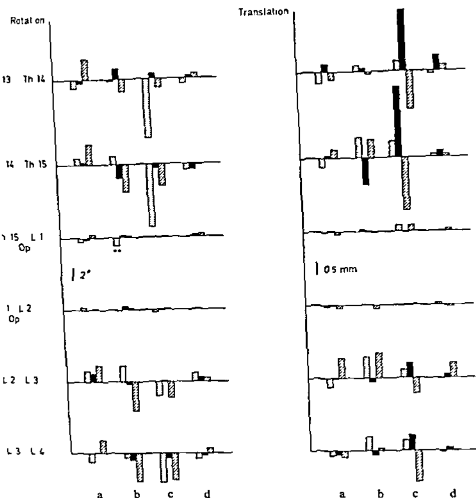


Fig 5 Pig 5 76 days after operation Graphic representation of the in vivo examination of pig 5, performed 76 days postoperatively with a bending moment of 10 Nm For further explanation see Fig. 1

the fused segments is large in both types of motion The curves for the latter segments (Figs 7, 8) reveal that a rotation ≥2 4° on lateral bending is measured in vivo between L3 and L4 The corresponding value for this segment pair post mortem is 3 1° The motion at extension flexion at the same level is ≥2 2° in vivo and 1 3° post mortem The rotations of L2 in relation to L3 are ≥1 5° for lateral bending in vivo, with a value of 1 4° for the specimen Extension-flexion is ≥1 0° and 0 7°, respectively, for the same segments L1 moves ≥2 3° from side to side in relation to L2 during life and 1 3° post mortem Corresponding values for extension-flexion are ≥0 4° and 1 1°, respectively

The second pig, in which L2–L4 were operated upon, developed only one rigid

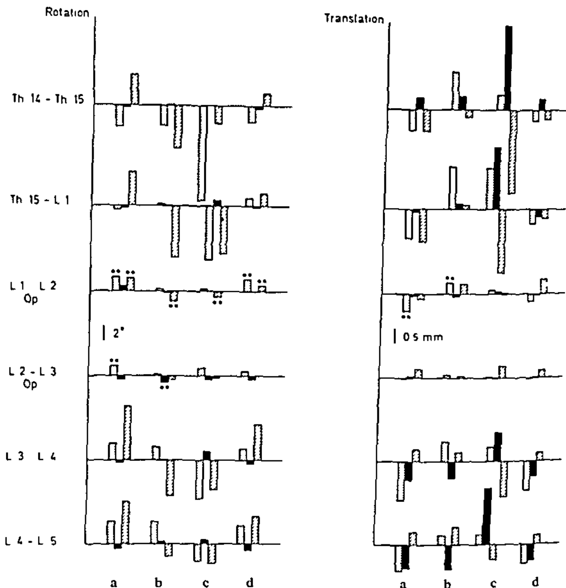


Fig 4 Pig 4 76 days after operation Graphic representation of the in vivo examination of pig 4 performed 76 days postoperatively with a bending moment of 10 Nm For further explanation see Fig 1

to their subjacent ones, when they have been provoked by lateral bendings from side to side and from extension to flexion with the bending moments given in the Figures The angles are plotted for L1–L2, L2–L3 and L3–L4 separately, while a mean value has been calculated for the remaining control segment pairs L1–L2 was originally supposed to be a control segment pair The reason why it became part of the rigid area is a postoperative, purulent wound infection, due to streptococci It was cured by penicillin, but nevertheless rigidity developed between L1 and L2 A difference of motion between the fused and the control segment pairs was not demonstrated until 93 days postoperatively (Figs 7, 8) The difference is most evident for extension-flexion, but is also seen in lateral bending At 133 days the difference between the control and

Table 1

The mean values for the mean errors of rigid body fitting for each segment of the five pigs The values were obtained during the examinations represented in Figs 1-6 The contribution of the measurement errors to the total mean error of rigid-body fitting as computed from the precision test

Segment No from behind	1	2	3	4	5	6	7
Pig 1	33*	42	40	66	82	68	55
Pig 2	48	48	18	25	44	35	31
Pig 3	45	45	29	61	55	40	62
Pig 4	44	37	74	55	99	20	65
Pig 5 in vivo	30	31	78	74	30	48	123
Pig 5 specimen	15	20	43	38	27	24	85
Precision test							
Pig 2	25	33	28	35	25	32	32
Pig 5 in vivo	20	33	55	48	48	36	45
Pig 5 specimen	16	20	28	30	18	23	24

* Unit μm

Table 2

The standard errors for the Eulerian rotations (s_ϕ, s_ψ, s_θ) about the three coordinate axes, and the standard errors for the translations (s_x, s_y, s_z) along these axes as well as the standard errors s_{rot} for the total rotation of one segment relative to an adjacent one, as computed from the precision test Degrees of freedom for each value ≈ 12

	s_ϕ	s_ψ	s_θ	s_{rot}	s_x	s_y	s_z
Pig 2	0 26*	0 16	0 27	0 41	44**	15	83
Pig 5 in vivo	0 44	0 29	0 27	0 60	94	39	194
Pig 5 specimen	0 27	0 25	0 10	0 39	42	14	75

* Unit degree ** Unit μm

tions about and along the x-axis, filled staples represent the movements relative to the y-axis, and striped staples those relative to the z axis

Only examples of those values of the fused vertebrae that are significantly different from zero at the 1 % level according to the precision test (these values are marked ** on the diagrams) will be mentioned here The first two pigs, which were smaller than the other three, have been evaluated according to the precision test of the second pig, while the test of pig 5 was applied to pigs 3 to 5

The rotations and translations about and along the x-, y- and z-axes are referred to as α_x, α_y, α_z and d_x, d_y, d_z, respectively Thus Fig 1 represents the motions between the adjacent vertebrae of the first pig, when examined 133 days after the operation and subjected to a bending moment of 4 5 Nm It is seen that the rotations α_x and α_y for L1 relative to L2 in the case of lateral bending to the right are 1 5° and 0 9°, respec-

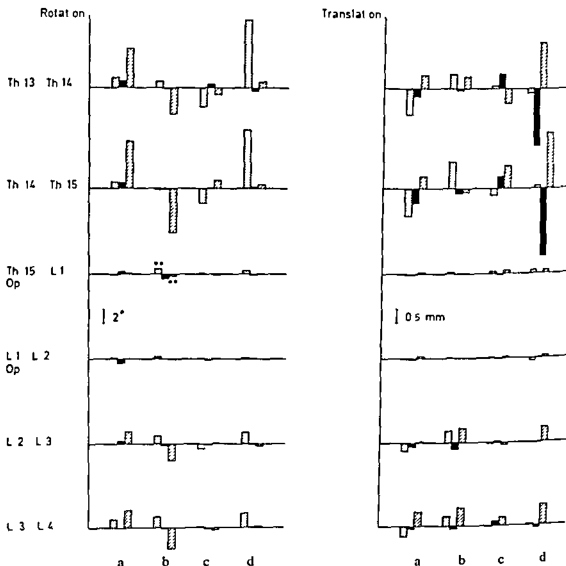


Fig 6 Pig 5 Specimen Graphic representation of the post mortem examination of pig 5 performed with a bending moment of 4 2 Nm For further explanation see Fig 1

level, i e L3–L4 (Figs 9, 10) Thus, 55 days postoperatively L3 rotated 3 2° from side to side and 2 2° at extension flexion relative to L4 At 84 days the corresponding values were 1 7° and 1 1°, respectively, while 2 2° and 1 9° were obtained post mortem The motions between the control segments varied with the bending moments, but they exceeded or equalled 6 6° from side to side and 7 4° at extension flexion Corresponding values for L2 in relation to L3 were > 5 7° and >4 7°, respectively

The rotations and translations about and along the three axes in space (see Fig 2, Olin et coll 1976), for the finally achieved motions between the vertebrae of the five pigs are graphically presented in Figs 1 to 5 In addition, the post mortem examination of the fifth pig appears in Fig 6 Stippled staples represent rotations and transla

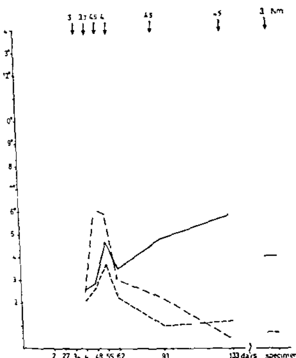


Fig 8 Pig I Extension-flexion The total angles of rotation from extension to flexion for the same segment pairs and the same examinations as in Fig. 7

movements about and along all axes between L2 and L3, when it was examined 84 days postoperatively (Fig 2) L3–L4, however, were stable in all examinations except lateral bending to the left, where a rotation $\alpha_z = 1\ 1°$ and a translation $d_y = 0\ 11$ mm existed At the L3–L4 level, the rotations post mortem were α_x 1 0° and $\alpha_z = 0\ 9°$ during lateral bending to the left and the rotation $\alpha_z = 0\ 9°$ during bending to the right Extension caused the rotations $\alpha_x = 2\ 0°$, $\alpha_y = 1\ 0°$, and $\alpha_z = 0\ 8°$ These provoked motions were all accompanied by significant translations, e g $d_x = 0\ 13$, $d_y = 0\ 10$, and $d_z = 0\ 87$ mm during extension

The third pig, which was exposed to a bending moment of 10 Nm in vivo had no significant motion at all between L2 and L3, when examined 95 days postoperatively (Fig 3) For L3–L4 the rotations were $\alpha_x = 2\ 9°$ and $\alpha_z = 0\ 8°$ and the translation $d_z = 1\ 0$ mm during lateral bending to the left Lateral bending to the right caused the rotation $\alpha_z = 1\ 0°$ and the translation $d_y = 0\ 13$ mm At flexion, the rotation $\alpha_x = 1\ 7°$ and the translation $d_z - 0\ 37$ mm were registered The bending moment, applied to the specimen of the third pig, was 4 2 Nm, no significant values of motion for L2–L3 were found Concerning L3–L4, the rotation $\alpha_x = 1\ 7°$ and the translations $d_y = 0\ 17$ and $d_z = 0\ 88$ mm were computed at extension , whereas the other provocations did not cause any significant motions

The fourth pig, examined 76 days postoperatively and subjected to a bending moment of 10 Nm, revealed significant rotations for L1–L2 about different axes in all

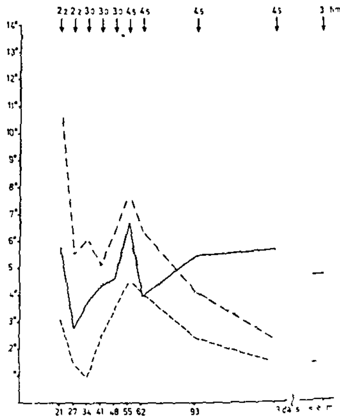


Fig 7 Pig I Lateral bending left-right The total angles of rotation

L3–L4 are plotted separately while a mean value for Th15–L1, L4–L5 and L5–L6 have been calculated - - L1–L2, --- L2–L3, L3–L4 —— Mean of control segment pairs

tively, and that the corresponding translations d_x and d_y are 0 13 and 0 27 mm During *flexion the rotation* α_x for L2–L3 is 1 2° and the translations d_x, d_y and d_z are 0 27, 0 06 and 0 59 mm, respectively At extension α_y −0 6° with d_x −0 26 and d_z =0 38 mm for this level Between L3 and L4 all the provoked motions caused significant rotations about different axes Thus during lateral bending to the left the rotation α_x is 0 8° and the translations d_x =0 14 mm and d_y =0 15 mm Lateral bending to the right causes the rotation α_z = 1 6° and the translations d_x and d_y are both equal to 0 15 mm At flexion α_x is 1 7° During extension there are the rotation α_y =0 6° and the translations d_x −0 30, d_y −0 13 and d_z =0 28 mm The post mortem examination (not graphically represented) was performed with a bending moment of 3 1 Nm and revealed that the rotations α_z for L1–L2 were 0 7°, 0 6° and 0 4° during lateral bendings to the left and right and flexion, respectively The translations d_x and d_y were 0 18 and 0 05 mm during lateral bending to the left For lateral bending to the right and extension, the translations d_y were 0 11 and 0 14 mm, respectively For L2–L3 there were significant translations during all provoked motions Thus, for lateral bending to the left, the translations d_x and d_y were 0 22 and 0 08 mm, respectively, and the rotation α_z =0 8° The rotations α_z for L3–L4 were 2 1° and 1 0° during lateral bendings to the left and right, respectively, and the rotation α_x was 1 3° at extension In the case of all these provoked motions there were also significant translations

The second pig, to which was also applied a bending moment of 4 5 Nm, had large



a



b

Fig. 11 a) Pig 3 Bilateral bony union between L2 L3 Fissure on the left side between L3 L4 b) Pig 3 Detail from 11 a demonstrating the fissure to better advantage

vertebrae of the first pig existed Thus, fissures were found between L2–L3 and L3–L4 and at provocation movements could be observed Complete bony union between L2 and L3 existed bilaterally in the specimen of the third pig (Fig 11 a) A bony bridge on the right side between L3 and L4 was encountered, while a deep fissure on the left side at this level was found (Fig 11 b)

In the fourth pig bony fusion bilaterally between L2 and L3 existed, while fissures with some minor bone bridges were observed between L1 and L2 (Fig 12) The fifth animal had developed a smooth bony union at both operated levels on both sides (Fig 13)

Discussion

Although the healing process of the first pig was delayed by infection, the continuous curves obtained by repeat examinations of the first two pigs demonstrate that it is possible to follow at successive intervals the healing process of a fused area with the method employed The results obtained—four segment pairs were comparatively rigid—indicate that stability in a fused area of a growing pig, does not develop until about 40 to 60 days postoperatively

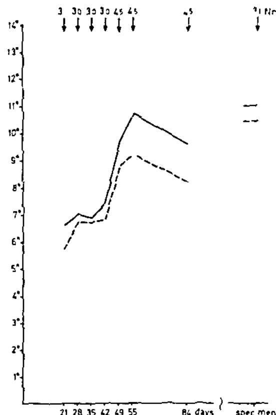


Fig 9

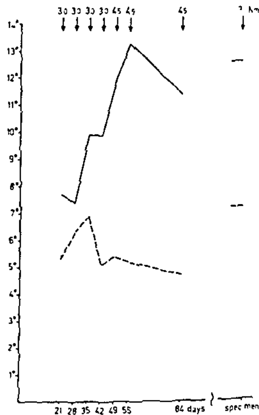


Fig 10

Fig 9 Pig 2 Lateral bending left–right The total angles of rotation for the lateral bendings from side to side between L2–L3 and L3–L4 and the mean values for the same angles between the control segment pairs at the different examinations

Fig 10 Pig 2 Extension–flexion The total angles of rotation from extension to flexion The segment pairs and the examinations are the same as in Fig 9

directions (Fig 4) For lateral bending to the left there were the rotations $\alpha_x = 2.0°$ and $\alpha_z = 1.8°$ with the translation $d_x - 0.63$ mm Concerning L2–L3, only two significant motions were observed the rotations $\alpha_x = 1.5°$ and $\alpha_y - 0.9°$ for lateral bending to the left and right, respectively When the specimen was subjected to a bending moment of 4 2 Nm, the rotation $\alpha_z = 0.6°$ was found for L1–L2 during lateral bending to the right and the translations $d_z - 0.29$, $d_x = 0.20$, and $d_y - 0.40$ mm for lateral bending to the left and right as well as at extension, respectively No significant motion of L2 relative to L3 was observed

The fifth pig, also subjected to a bending moment of 10 Nm during the examination 76 days postoperatively, disclosed only one significant motion of the operated segments A rotation $\alpha_x = 1.4°$ between Th15 and L1 was found for lateral bending to the right When the specimen was loaded by 4 2 Nm, the rotations $\alpha_x = 0.8°$ and $\alpha_z = 0.4°$ were recorded for Th15–L1 during the same lateral bending, while the other values were insignificant (Fig 6)

The inspection of the specimens revealed that no fusion between the operated

(Fig 11 b) Thus, when the fissure widened or the distance between the vertebral bodies increased, the described motion was made possible

The fourth pig had two rotations between $\alpha_x = 1\ 5°$ and $\alpha_y = 0\ 9°$ in vivo, that were significantly different from zero ($p < 0\ 01$) while the others were not Both rotations, however, are border line values Considering that, post mortem, no significant motion at all was found for L2-L3, it is concluded that this level is stable Macroscopically, bony union existed bilaterally at this level (Fig 12) The other operated level, L1-L2, of the fourth pig moved significantly both in vivo and post mortem For example, the rotations α_z are during all provoked motions in vivo (Fig 4) significantly different from zero ($p < 0\ 01$) and the rotation $\alpha_x = 2\ 0°$ is highly significant ($p < 0\ 001$) Macroscopically, bilateral fissures with minor bony bridges were observed (Fig 12) Therefore the calculated motions might be regarded as the consequence of an elastic deformation of these bony bridges

In vivo only one significant motion at the levels of operation was found in the fifth pig (Fig 5) i e the rotation $\alpha_x = 1\ 4°$, a value close to the limit of significance Post mortem, only two values of motion significantly different from zero, were found—the rotations $\alpha_x - 0\ 8°$ and $\alpha_z = 0\ 4°$—both border line values Thus it may be concluded that the segments were stable in relation to each other, this conclusion was verified by the macroscopic inspection of the specimen, which revealed a bony union bilaterally on both levels of operation (Fig 13)

Thus the roentgen stereophotogrammetric method used, renders it possible to follow the healing process of spinal fusions It also makes it possible to detect and quantify the motion in such fusions If the method be applied in clinical practice, the diagnosis of pseudoarthrosis in a fused area can in the future be settled more accurately than in in the past, a fact that may overcome the discrepancy between the clinical and roentgenologic results reported previously (CLEVELAND et coll 1948)

SUMMARY

Five pigs operated upon by posterior spinal fusion were examined by a roentgen stereophotogrammetric method during provoked motion The healing process leading to marked rigidity within the spine was followed in two of the pigs Varying degrees of stability in the fused area were achieved in the five animals Movements were detected, not only when the fusions were not healed but also in two cases of incomplete bony union between two operated segments

ZUSAMMENFASSUNG

Funf Schweine die mit hinteren Wirbelverbindung operiert worden waren wurden mit einer stereophotogrammetrischen Rontgenmethode im Verlauf provozierter Bewegung untersucht Der Heilungsprozess der zu einer ausgepragten Rigidität zwischen den Wirbeln fuhrte wurde bei zwei der Schweine verfolgt Verschiedene Grade von Stabilitat des vereinigten Gebietes wurden bei den funf Tieren erreicht Es wurden Bewegungen nachgewiesen nicht nur wenn die Verbindung nicht geheilt war sondern auch in zwei Fällen inkompletter Knochenverbindung zwischen zwei operierten Segmenten



Fig 12

Fig 12 Pig 4 Fissures between L1–L2 coloured black Minor bony bridges are present bilaterally Bilateral bony fusion between L2 L3

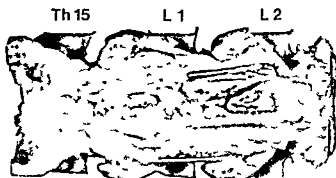


Fig 13

Fig 13 Pig 5 Bony union at both operated levels on both sides

The first pig developed a comparatively stiff back from L1 to L4, but had significant motion at all these three levels (Fig 1) Fissures were found between L2 and L3, and between L3 and L4, with a slight displacement visible at both levels

The second pig developed no fusion between L2 and L3, though a diminished motion at this level was found at extension-flexion (Figs 2, 10) At the L3–L4 level the rotation was $\alpha_z - 1\ 1°$ for lateral bending to the left with the translations d_x 0 13 and $d_y - 0\ 11$ mm in vivo This fact, together with significant motions during three of the four provocations post mortem, indicate that a complete bony union had not been obtained in this pig Unfortunately, however, this is not quite certain, because the specimen was lost before the macroscopic inspection

Neither the in vivo, nor the post mortem examination, revealed any significant values of motion for L2–L3 of the third pig Bony fusion was also found bilaterally when the specimen was inspected (Fig 11 a) The other operated segment pair of the third pig, L3–L4, rotated in relation to each other (Fig 3), e g $\alpha_x = 2\ 9°$, $\alpha_z - 1\ 7°$ obtained at provoked lateral bending to the left and at flexion, respectively These values are valid for lordosis and a curve with convexity towards the left side, respectively This appearance of motion is explained by the fact that in spite of a bony union on the right side, a fissure between L3 and L4 on the left side existed

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SPINAL CORD VASCULARITY

IV The spinal cord arteries in the rat

LEON TVETEN

WOOLLAM & MILLEN (1955) who gave the first description of the vascular anatomy of the spinal cord of the rat were struck by the close similarity to that of man In a comparative anatomic investigation of various laboratory animals JELLINGER (1966) also called attention to a number of common vascular features similar in man and the rat Other reports (BRIGHTMAN 1956, SOUTOUL et coll 1964) have largely confirmed these observations All these authors used isolated cords so that the exact position of the spinal cord tributaries and the arrangement of minute blood vessels may have been difficult to ascertain Moreover, the series of animals were too small to give statistically significant results

The intention to use rats for experiments on vascular myelopathy made it necessary to evaluate the vascular arrangement of the spinal cord of the rat with modern microangiographic and stereomicroscopic techniques (TVETEN 1976 a b)

The main intention was to investigate (1) the arrangement of spinal cord tributaries in a statistically significant number of animals, (2) the arrangement of arteries on the surface and within the spinal cord substance, especially with regard to the regional distribution of the central arteries and their area of supply, and (3) the occurrence of intramedullary anastomoses

From the Institute of Pathology Section of Neuropathology, University of Oslo Rikshospitalet, Oslo Norway Submitted for publication 5 December 1974

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RÉSUMÉ

Cinq porcs opérés par fusion vertebrale postérieure ont été examinés par une methode stéréophotogrammétrique au cours de mouvements provoqués Le processus de guérison conduisant à une rigidité importante du rachis a été suivi chez 2 de ces porcs On a obtenu divers degrés de stabilité dans la région opérée chez les 5 animaux Les auteurs ont observé des mouvements non seulement quand les functions vertébrales n'étaient pas consolidees mais aussi dans 2 cas d'union osseuse incomplète entre les 2 segments operés

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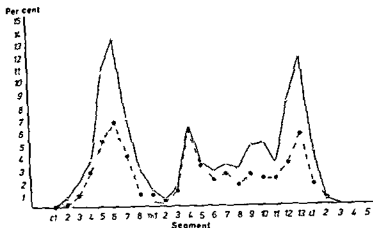


Fig 3 Segmental distribution of ventral radicular arteries in per cent of the total number in 115 rats ● ● left ○ ○ right △—△ total

Material and Methods

The material included spinal cords from 115 young and adult rats used in an investigation of the extraspinal arteries (TVETEN 1976 b) The specimens were subjected to radiography, made transparent and photographed according to methods previously described (TVETEN 1976 b)

Whole specimens and segments of the spinal cord cut in the transverse or longitudinal planes were examined by radiography and stereomicroscopy in different positions with the specimens placed either in thin polyethylene bags or submerged in oil of wintergreen Examination of small arteries and capillaries was performed on formalin fixed material embedded in paraffin wax and cut in the sagittal coronal and transverse planes The sections were about 20 μ in thickness They were made transparent in the usual way mounted on slides and examined beneath a binocular microscope

Results

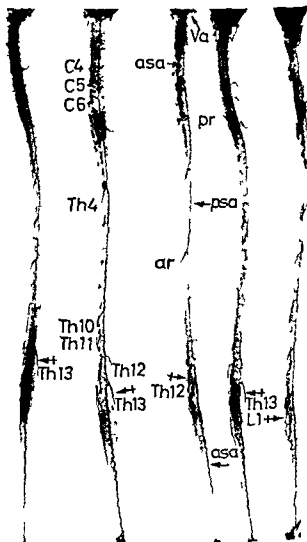
The radicular arteries

As in man the middle branch of the spinal artery in the rat divided outside the dura mater into a ventral and a dorsal root artery (Fig 1) Most of these arteries branched only along the nerve roots A limited number of vessels reached the surface of the cord extending along the ventral aspect of the nerve roots

The number of ventral and dorsal spinal cord tributaries branching from a common stem i e from the same spinal artery varied from 0 to 9 in individual cases giving an average of 5 This was more frequent at levels of the spinal cord enlargements, predominantly at C4, C5 and C6 than in other regions In the lumbar enlargement

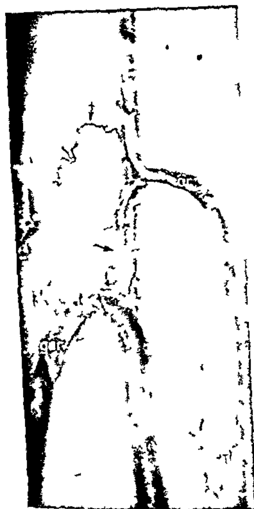


Fig 1 Transparent specimen, photography Cross section of the cervical *spine of the rat with the cord intact,* a spinal branch of the vertebral artery *dividing outside the dura mater* (→) and giving rise to a ventral (ar) and a dorsal (pr) root artery *Spinal cord* (Sp) (5 8)



F[illegible] aphy of 5 rats The [illegible]

and dorsal [illegible]
(asa) and dorsal (psa) spinal arteries, the great ventral root artery (↔) vertebral arteries (Va) (×0 9)



F g 5 The branch ng of the artery of Adam k ewicz great ventral root artery (gar) Its slender ascending branch (—>) connects to a smaller ventral root artery (ar) immed ately above rare occurrence of arterial branches to the circumference of the cord (+→) (18 9)

One artery larger than others in the series the great ventral rad cular artery was invar ably present at the thoracolumbar border (Fig 2) though the orig n of the artery varied from Th11 to L2 (Fig 4) In about two th rds of the specimens it arose from the subcostal space (Th13) sl ghtly more often from the right than from the left s de A lumbar orig n of the artery was observed in about 10 per cent of the animals only In about one fourth of the cases that displayed a thoracic orig n of the great ventral rad cular artery one or two additional small branches were found in the upper lumbar cord In the vast majority of cases however the great ventral rad cular artery was the only ventral tributary to the lower thoracic and lumbo-sacral cord In about half the cases (55/115) the artery was followed by a sign ficant dorsal root artery branching from the same spinal artery most frequently on the right s de of the subcostal space

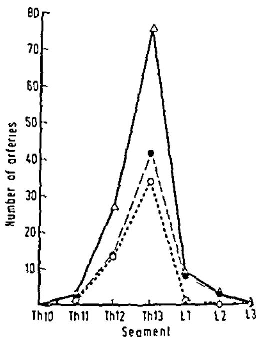


Fig. 4 Location of the great ventral root artery of Adamkiewicz in 115 rats ●---● right, ○----○ left, —△ total

it occurred mainly on the left side while there was a slight predominance on the right side in the cervical region Most often, however, significant ventral and dorsal root arteries arose separately

The ventral root arteries provided the main blood supply to the cord On reaching the ventral surface of the cord each artery divided near the ventral median fissure into an ascending and a descending branch These branches united with those from above and from below to form the ventral spinal artery (or the ventral anastomotic chain) which extended the entire length of the cord and terminated into the filum terminale (Fig 2)

The size, number and position of the ventral root arteries varied considerably in individual cases Their total number ranged from 3 to 14, averaging 7 and was slightly larger on the left than on the right side The excess in vessels entering the left side of the cord was particularly evident at the levels where the aorta is normally positioned to the left of the vertebral column, as in the middle and upper thoracic cavity The variation in number of arteries in different regions of the cord was in the cervical region from 1 to 7, average 3, in the thoracic region from 1 to 8, average 4 and in the lumbar region from 0 to 2, average 0 to 1

In the cervical region there was a predominance of arteries at C5 and C6 and they entered from the right almost as frequently as from the left side of the cord (Fig 3) In the thoracic region there was a remarkably poor supply of root arteries to the upper three segments, and in the upper middle part of the region (Th4 to Th7) there was also an excess of vessels entering from the left side On the other hand, in the lower thoracic and in the lumbar region a slight predominance of arteries from the right side existed



F g 5 The branching of the artery of Adam kiew cz great ventral root artery (gar) Its slender ascend ng branch (→) connects to a smaller ventral root artery (ar) immediately above rare occurrence of arterial branches to the circumference of the cord (↔) (18 9)

One artery larger than others in the series the great ventral radicular artery was invariably present at the thoracolumbar border (Fig 2) though the origin of the artery varied from Th11 to L2 (Fig 4) In about two thirds of the specimens it arose from the subcostal space (Th13) slightly more often from the right than from the left side A lumbar origin of the artery was observed in about 10 per cent of the animals only In about one fourth of the cases that displayed a thoracic origin of the great ventral radicular artery one or two additional small branches were found in the upper lumbar cord In the vast ma or ty of ca e

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g i om the same spinal artery, most frequently on the right side of the subcostal space

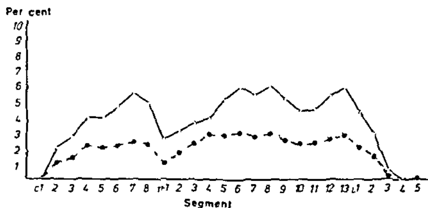


Fig 6 Segmental distribution of dorsal radicular arteries in per cent of the total number in 115 rats (Symbols as in Fig 3)

The great ventral radicular artery usually divided at some distance from the ventral median fissure into a large descending and a small ascending branch The former represented the main arterial supply to the lumbosacral cord and, as in man, it tapered towards the filum terminale The ascending branch was not infrequently poorly developed and joined the descending branch from an intercostal artery at a variable distance (Fig 5)

The dorsal radicular arteries were smaller but more numerous and more evenly distributed than their ventral counterparts (Fig 6) The number of arteries joining the dorsal spinal arteries varied from 16 to 35 in individual cases The average was 25 including 7 in the cervical region (range 3 to 11), 15 in the thoracic region (range 9 to 22) and 3 in the lumbar region (range 1 to 5) As for the ventral root arteries, a profuse supply to the spinal cord enlargements and a relatively poor supply in the upper thoracic cord was evident (Fig 6) Not infrequently the arteries entered the same spinal cord segment from both sides, though, as a rule, most arteries were unilateral The incidence of vessels arranged symmetrically varied individually from 21 to 78 per cent with an average of about 40 per cent In about one fourth of the animals their number exceeded that of arteries arranged unilaterally

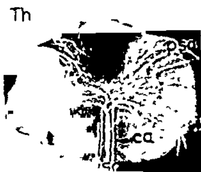
Dorsal root arteries in the lower lumbar and sacral region usually pierced the tip of the dorsal grey horn and soon terminated in the grey and white matter However, a variable number of these arteries ran into conspicuous anastomoses with intramedullary branches from the ventral spinal artery (Figs 7d, and 8a, b)

The surface arteries of the spinal cord

The surface of the spinal cord of the rat presented three longitudinal arterial channels or trunks, a single ventral and a paired dorsal, extending more or less the entire length of the cord (Fig 2) They are formed by anastomoses of the ascending and descending branches of the root arteries



a



b



c



d

The ventral spinal artery extended from the junction of the ventral spinal rami of the vertebral arteries to the filum terminale, in front of or near to the ventral median fissure Not infrequently narrow parts of the artery were found at the union with the ascending branch of the great ventral radicular artery and also in the upper and middle thoracic cord (Fig 2) Contrary to the condition in man, the artery of the rat was rarely divided into two branches forming a diamond-shaped figure, especially at sites where the radicular arteries joined it from both sides, as in the cervical region (Fig 2) As in man, the artery gave rise to branches traversing the ventral median fissure (central arteries) while branches to the circumference of the cord were rarely observed (Fig 5)

The paired dorsal spinal arteries, one on each side (Fig 2), were situated on the dorso-lateral surface of the spinal cord, usually ventral to the dorsal rootlets At the upper end the artery most often came from the dorsal spinal ramus of the vertebral

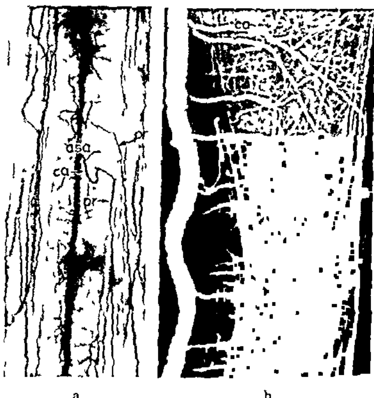


Fig 8 a) Dorsal view of transparent specimen (× 5 9) b) Lateral angiographic view (× 11 8) Intramedullary anastomoses (←→) between central branches (ca) from the ventral spinal artery (asa) and penetrating branches from dorsal root arteries (pr) in the lower lumbar cord Central arteries (ca) branching from a short common stem

artery, occasionally from the inferior dorsal cerebellar artery In a few specimens the C2 or C3 dorsal radicular arteries formed the cephalic end At the caudal end the artery usually tapered off at the border between the lumbar and sacral segments The size was markedly smaller than that of the ventral spinal artery Splits, short breaks and a winding course were not infrequent findings in the cervical region, sometimes also in the middle or upper thoracic region, especially at levels where slender root arteries joined the artery The two arteries interconnected by way of inconstant, small oblique or transverse branches crossing the dorsal surface of the cord, most often seen at the cervical and lumbar cord enlargements At regular intervals branches were given off penetrating the tip of the dorsal grey horn to supply the dorsal grey and white matter of the cord Occasionally small twigs were distributed to the dorsal rootlets and the upper part of the dorsal nerve roots, especially those of the lumbosacral region

The intrinsic arteries of the spinal cord

As in man, the blood supply to the spinal cord of the rat may, according to the direction of blood flow, conveniently be divided into two different arterial systems, one central and one peripheral

The central arterial system in which the direction of blood flow is centrifugal, includes the central or sulcus arteries from the ventral spinal artery The main blood supply of the cord is derived from this system

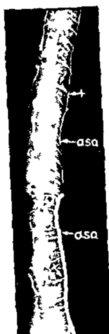


Fig 9 Lateral angiographic view of a longitudinal section of the lower thoracic and upper lumbar cord, origin and branching of the central arteries (→) Arteries arising on a short common stem (↔) The ventral spinal artery (asa) (× 1 8)

The peripheral arterial system in which the direction of blood flow is centripetal, comprises penetrating branches from the dorsal spinal arteries and branches from the ventral root arteries following the nerve fibers into the ventral grey horn

The central arteries branched from the dorsal aspect of the ventral spinal artery and traversed the ventral median fissure to gain the base of the ventral grey horn They terminated into a rich vascular plexus supplying the main parts of the grey and the white matter In places where the ventral spinal artery was situated at some distance from the midline of the cord, the central arteries passed the ventral surface of the cord before entering the fissure As a rule, they arose singly and passed alternately to the right and the left side of the cord Not infrequently, however, two arteries branched from a short common stem dividing in the sagittal plane (Fig 9) Sometimes two, rarely three, consecutive arteries entered the same side of the cord

The total number of central arteries in 25 adult rats varied from about 200 to 230, averaging 220 They were more closely packed in the lumbar enlargement than in any other part of the cord The average number pro 1 cm of the cord was in the cervical region 26, in the middle of the thoracic region 14, and in the lumbar region 32 When close together as in the lumbar and the cervical region the arteries branched more or less horizontally while the more widely spaced arteries in the thoracic region branched predominantly in the longitudinal plane Sometimes twigs in the thoracic region extended over 2 to 3 segments interdigitating with corresponding branches



Fig 10 Transparent specimen, photography Small intramedullary arteries and capillaries a) The artery dividing at the periphery of the grey matter supplies branches to the white matter (→) The capillary network is discernible Ventral spinal artery (asa), central artery (ca) Surface of the cord (↔) (× 13 8) b) Magnification of the inset in (a) (× 55 2)

from neighbouring central arteries The degree of overlapping varied in different regions of the cord, being smallest in the lumbosacral cord

Most of the branches of the central arteries coursed to the periphery of the grey matter before they divided into terminal arterioles Some of these arterioles turned back to the center of the ventral grey matter branching into capillaries while others travelled deep into the white matter to supply the ventral and lateral funiculi (Fig 10 a, b) At the base of the dorsal grey horn and in the ventral part of the dorsal white matter, branches from the central arteries overlapped with penetrating branches from the dorsal spinal arteries Occasionally branches from the central arteries extended deep into the dorsal white matter along the dorsal median septum No connection between the terminal arterioles of the central arteries was ever observed

The penetrating branches from the dorsal spinal artery were more widely spaced than the central arteries and pierced the tip of the dorsal grey horn more or less obliquely They turned rostrally and branched in the longitudinal and transverse planes to supply the dorsal grey and white matter and also some of the dorso lateral white matter Terminal arterioles from these branches overlapped both in the longitudinal and the transverse plane but made no connections above the capillary level

It should be noted that no penetrating branches were observed at other sites of the circumference of the spinal cord, except those occasionally running along the ventral rootlets It also should be emphasized that no arterial branches above the size of capillaries were ever seen in the pia mater, except those occasionally interconnecting the two dorsal spinal arteries

The capillaries within the spinal cord

Like the situation in man, the grey matter of the spinal cord of the rat was clearly defined by its extensive capillary network, less well marked in the dorsal grey horn than in the ventral and lateral grey horns The meshes of the network in the enlargements of the cord seemed to be stretched mainly in the transverse plane while those in the thoracic cord appeared slender, less concentrated and distributed predominantly in a longitudinal direction

In the white matter the pyramidal tract, which in the rat is located in the ventral part of the dorsal funiculus, seemed to be the one best supplied

Discussion

The arrangement of the spinal cord arteries in the rat was to a large extent found to correspond to previous descriptions There were, however, some differences in essential details from previous accounts

WOOLLAM & MILLEN, in a series of 16 rats, regularly observed the great ventral radicular artery in the lumbar region running along the second or the third lumbar nerve root, in contrast to the present finding of an almost constant position of this artery in the subcostal space The authors described the artery in some detail and concluded that its branching was essentially similar to the great anterior radicular artery of Adamkiewicz in man The present findings supported this view, while GILLILAN (1958) suggested that the course of the artery in rats differed from that in man JELLINGER stated that the main supply to the lumbar cord in rats was by way of paired ventral feeders, equal or unequal in size, rather than a single, large artery in the upper lumbar region He also described a great dorsal radicular artery as a constant finding at the level of these arteries In the present material a particularly large radicular artery to the dorsal surface of the cord was never observed, but some arteries in the lower thoracic and lumbar region were more prominent than others Moreover, in less than half of the cases a dorsal spinal cord feeder was found branching from a common stem with the great ventral radicular artery WOOLLAM & MILLEN believed that the latter was always the sole source of supply to the whole lumbosacral cord, additional tributaries below its entrance could be demonstrated in a comparatively large number of specimens in the present material

The strict lumbar position of the great feeder of the lumbar cord of the rat has been emphasized (WOOLLAM & MILLEN, BRIGHTMAN, SOUTOUL et coll, JELLINGER) SOUTOUL et coll even stated that in primates only the artery may be found at a thoracic level It was, however, from the present results evident that the position of the great ventral radicular artery in rats was subjected to greater variations than previously believed and that a lumbar origin of the artery was rather a rare event The fact that this important spinal cord feeder in the vast majority of cases arose from the subcostal space or, less often, from the lower intercostals might be of practical importance in experiments creating vascular myelopathies

The poorly vascularised watershed between tributaries from the vertebro subclavian arteries and the aorta was *particularly evident in the rat* JELLINGER believed that the anatomic border between the two systems in the rat corresponded to that in man, i e being localized to C8–Th1 *In the present material it was found* at Th1–Th2 in about half the specimens and varied from C8 to Th3 in individual cases In other reports it was demonstrated (TVETEN 1976 a, b) that the poor supply of tributaries to the upper thoracic cord corresponded fairly well with the distribution area of the superior intercostal artery from the costocervical trunk in man and rat

As in man (TVETEN 1976 c), most of the ventral feeders to the thoracic cord of the rat were found to enter mainly from the left side, except the one in the subcostal space while JELLINGER suggested that the tributaries in rats were most often arranged symmetrically on the two sides

The mode of union of the radicular arteries with the ventral and dorsal spinal *arteries* observed in the present material lends strong support to the view that the longitudinal trunks are essentially anastomotic chains, as stressed by WOOLLAM & MILLEN *Like the situation* in man, parts of these chains were sometimes ill defined due to tiny connections between adjacent root arteries and short breaks in the dorsal chains were not infrequent The ventral chain, however, was always continuous

BRIGHTMAN mentioned an additional longitudinal trunk on the lateral surface of the spinal cord of the rat and claimed that the surface arteries of one half of the cord interconnected extensively by way of pial branches CRAIGIE (1931) also believed in free anastomoses between small circumferential branches from the ventral and dorsal spinal arteries and described a highly vascular pial plexus supplying branches to the white matter of the cord Longitudinal arterial trunks on the lateral surface of the spinal cord of the rat were never observed in the present material Neither supracapillary anastomoses between the surface arteries nor penetrating branches from the pial plexus were observed The two dorsal spinal arteries, however, interconnected by way of branches crossing the dorsal surface of the cord and the ventral and dorsal spinal arteries occasionally interconnected through rami cruciantes at the lower end of the cord Little regularity and no constancy in these interconnections could be discerned Most of the vessels in the vascular plexus of the pia were found to be veins (TVETEN to be published)

Fom these anatomic observations it may be concluded that the ventral and the dorsal spinal arteries in the rat represent two independent systems of spinal cord arterial supply, being more strictly demarcated than those in man

The demonstration of intramedullary connections between the dorsal root arteries and the central branches of the ventral spinal artery in the lumbosacral cord is interesting since it is generally stated that the terminal arterioles do not connect within the substance of the spinal cord The functional significance of such anastomoses which to the best of our knowledge has not been described previously, remained to be solved and is discussed elsewhere (TVETEN & LOKEN 1975)

The present investigation of the intrinsic blood supply of the spinal cord of the rat showed that the central arteries supplied most of the nervous tissue except the dorsal white and most of the dorsal grey matter The origin, course, number of arteries and density of distribution in different regions of the cord closely parallelled those previously found in human infants and also agreed with the findings of WOOLLAM & MILLEN in rats These authors believed contrary to CRAIGIE and ZEMAN & INNES (1963) that the white matter of the spinal cord of the rat was supplied by the capillary bed of the grey matter since no arterioles were observed in the former

Arteriolar branches from the central arteries extending far into the ventral and lateral funiculi before they terminated into capillaries could be demonstrated in the present material Furthermore, it was shown that the branches overlapped with branches from the dorsal spinal arteries in a manner similar to that observed in man giving rise to watershed areas in the basal part of the dorsal grey horn

SUMMARY

The present investigation has shown that the anatomy of the spinal cord arteries in the rat and in man is closely related but not identical The main differences are (1) The poor supply of radicular arteries to the lower cervical and upper thoracic segments of the cord is more marked in the rat (2) the great ventral radicular artery of Adamkiewicz is less subjected to variations in position in the rat (3) penetrating branches from the pial arterial plexus are absent in the rat (4) surface anastomoses between the ventral and the dorsal spinal arteries do not occur in the rat except occasionally at the lower end of the cord Intramedullary arterial anastomoses in the lumbosacral cord of the rat seems to be species specific

ZUSAMMENFASSUNG

Die vorliegende Untersuchung hat gezeigt, dass die Anatomie der Arterien der Wirbelsaule der Ratte und des Menschen einander sehr ahnlich aber nicht identisch ist Die wesentlichen Unterschiede sind (1) D [illegible]
Zervikal und ob [illegible]
ventrale A radi [illegible]
Variationen ausg [illegible] Äste von der Pia mater fehlen bei der Ratte, (4) oberflachlichen Anastomosen zwischen den ventralen und dorsalen Aa spinales sind nicht vorhanden Ausnahmen treten bei der Ratte gelegentlich auf Intramedullare arterielle Anastomosen der Lendenwirbelsäule der Ratte scheinen Art spezifisch zu sein

RÉSUME

Ce travail de recherche a montre que les anatomies des artères de la moelle epinière chez le rat et chez l homme sont etroitement apparentées mais pas identiques Les principales differences sont (1) la pauvreté de l irrigation par les artères radiculaires des segments cervicaux inférieurs et dorsaux superieurs de la moelle plus marquee chez le rat, (2) la grande artère radiculaire anterieure d Adamkiewicz est moins sujette à variation de sa

position chez le rat, (3) chez le rat il n'y a pas de branche pénétrante provenant du plexus artériel pial, (4) des anastomoses entre les artères spinales antérieures et postérieures n'existent pas chez le rat, sauf exception Les anastomoses artérielles intramédullaires de la moelle lombo-sacrée du rat semblent être spécifiques à l'espèce

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COMPUTER TOMOGRAPHY OF THE NEUROCRANIUM

B LILIEQUIST and Å FORSSELL

Lesions and malformations of the brain and its membranes may be reflected in abnormalities visible on conventional films of the skull Thus, skull films are almost indispensable in neuroradiology

Computer tomography was introduced in 1972 and has proved to be of the utmost value in the examination of various cerebral diseases The method is non invasive and has replaced cerebral angiography and encephalography in many situations In fact the daily work in a neuroradiologic department has completely changed since the introduction of computer tomography However, the attention has been focused mainly on the brain, the skull having been more or less neglected No reports on the appearance of the skull in computer tomography seem to have been published

This fact motivated the investigation now reported The interest was focused on those parts of the skull which are difficult to examine with the conventional technique, even if supplemented with tomography the posterior cranial fossa with the foramen magnum the temporal bone, the middle cranial fossa with the sella turcica and the anterior cranial fossa with the complex sphenoid bone

Technical considerations

In computer tomography information is gained not only from the attenuation properties of the brain substance, the blood vessels and the cerebrospinal fluid but

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also from those of the skull bone The attenuation values corresponding to bony tissue are high, in the range used in the first generation of EMI scanners represented by numbers around 400 When the brain is examined a window width somewhere between 10 and 100 is used and the level is defined by the EMI numbers most likely being of interest, i e usually between 10 and 30 This means that all the information outside the chosen interval remains unused, thus, the skull bones appear as a homo geneous structure To obtain an opportunity of using this 'hidden' information a wide window is required, extending the range of EMI numbers displayed in the grey scale to 400 The thickness of the section was always 13 mm

As in conventional skull examination different projections must be used for different regions of the skull, thus, the position of the skull should be considered carefully In the first generation of EMI scanners the choice of position is limited by the small size of the aperture and the water box and, therefore, appropriate projections cannot always be achieved In the second generation of skull scanners as well as in general purpose scanners these difficulties no longer exist and a suitable projection is easily chosen Finally the section should, as far as possible, include the whole anatomic structure of interest in order to avoid an erroneous evaluation of an incomplete or distorted image Further accuracy may be obtained by the use of techniques for reconstruction in other planes than those measured

Results

Posterior cranial fossa Anatomic details of interest in the posterior cranial fossa, which all are possible to demonstrate, are the foramen magnum (Fig 1) the hypoglossal canal (Fig 2), the jugular foramen (Fig 3) and the internal auditory canal (Fig 4) Details of the occipital bone such as the occipital condyles, the clivus and the inion (Fig 5) are well defined

Temporal bone Radiography of the temporal bone is most important in the diagnosis of middle ear disease as well as in the examination of malformations and destructive lesions of the middle and inner ear Conventional radiography including tomography is well established and the present experience indicates that it cannot be replaced by computer tomography However, the extension of the mastoid cells may possibly be better estimated by computer tomography than by conventional technique (Fig 6) The middle ear, the auditory tube and the outer auditory canal may be demonstrated with computer tomography (Fig 7) but not the ossicles or details of the inner ear The tip of the pyramid is visible and also the trigeminal impression (Fig 8)

Middle cranial fossa When the floor of the middle cranial fossa is included in the section the foramen lacerum and the foramen ovale are visible as well as the lateral borders of the clivus (Figs 1, 2, 5, 9) The anterior border of the middle fossa, the



Fig 1 Foramen magnum EMI numbers for WL (window level) = 168 and WW (window width) = 400



Fig. 2. Hypoglossal canal WL = 136, WW = 400



Fig 3 Jugular foramen WL = 179, WW = 400



Fig 4 Internal auditory canal WL = 497, WW = 400



Fig 5 Clivus, occipital condyles, inion WL = 64 WW = 400



Fig 6 Wide extension of mastoid cells WL = 118, WW = 400



Fig. 7 External auditory canal and middle ear WL = 193, WW = 400



Fig 8 Trigeminal impression WL = 113, WW = 400



Fig 9 Foramen ovale in middle cranial fossa WL = 194, WW = 400



Fig 10 Sella turcica WL ~ 55, WW ~ 200



Fig 11 Optic canal WL ~ 129, WW ~ 400



Fig 12 Anterior cranial fossa WL ~ 65, WW ~ 400



Fig 13 Diploe WL ~ 442, WW 400



Fig 14 Internal frontal hyperostosis WL ~ 478, WW 400

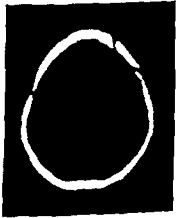


Fig 15 Bone flap WL 349, WW 400

greater wing of the sphenoid, appears as a curved bony structure in which the defect caused by the superior orbital fissure may be observed

The sella turcica is usually visible delineated posteriorly by the dorsum and the posterior clinoid processes and anteriorly by the limbus sphenoidalis and the anterior clinoid processes (Fig 10) When contrast enhancement is used the cavernous sinus and the carotid siphon appear adjacent to the sella

The optic canal and the relation to the optic nerve is clearly demonstrated (Fig 11)

Anterior cranial fossa Details in the anterior fossa suitable for examination by computer tomography are sparse The bony floor, like that of the middle fossa, have a wavy appearance corresponding to the impressions usually present (Fig 12) In an appropriate section the midline part of the floor, i e the lamina cribrosa may be evaluated as well as the extension of the ethmoid cells and the sphenoid sinus As a

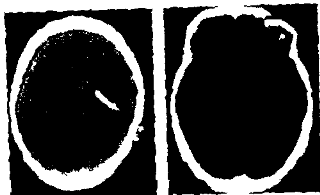


Fig 16 Shunt catheter with part of its extracranial portion WL =93, WW=400

Fig 17 Fracture with displacement WL=196, WW=400

preoperative examination of the anatomy of the paranasal sinuses including the sphenoid sinus and the sella turcica in cases of pituitary tumour, computer tomography is probably superior to other procedures

Calvarium Abnormalities in the calvarium may be evaluated by computer tomography An appropriate EMI number level allows an assessment of the calvarium and the extension of the diploe (Fig 13) The sutures are evident and premature synostosis is easily explored The local bony thickenings in internal frontal hyperostosis are well demonstrated (Fig 14)

Postoperatively the position of metallic clips in relation to the calvarium or other structures are easily defined (Fig 13) and the position of a bone flap determined (Fig 15) The intracranial part of shunt catheters can be located as well as their extracranial continuation (Fig 16) The extension of fractures and possible displacement of bone fragments may be determined (Fig 17) Probably fractures through the base of the skull are more easily evaluated with computer tomography than with conventional technique

SUMMARY

The experience with computer tomography of the neurocranium in 300 patients submitted for computer tomography of the brain is reported The more appropriate projections which may be obtained with the second generation of scanners in combination with an elaborated reconstruction technique seem to constitute a replacement of conventional skull films

ZUSAMMENFASSUNG

Im Zusammenhang mit Computer Tomographie des Gehirns wurde der Gehirnschädel bei 300 Patienten untersucht und die Erfahrungen werden vorgelegt Die Projektionen, die



Fig 10 Sella turcica WL = 55, WW = 200



Fig 11 Optic canal WL = 129, WW = 400



Fig 12 Anterior cranial fossa WL = 65, WW = 400



Fig 13 Diploe WL = 442, WW = 400

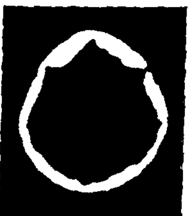


Fig 14 Internal frontal hyperostosis WL 478, WW 400

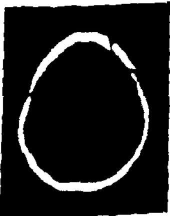


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COMPUTER TOMOGRAPHY IN THE EVALUATION OF PULMONARY ASBESTOSIS

Preliminary experiences with the EMI general purpose scanner

LOUIS KREEL

The effects of asbestosis include pulmonary fibrosis, pleural plaque formation (KIVILUOTO 1960, HURWITZ 1961, FREUNDLICH & GREENING 1967) and, in smokers, bronchial carcinoma and mesothelioma due to the power of the asbestos fibres to adsorb benzpyrene, the latter property being directly connected with the concentration of benzpyrene in the environment (SELIKOFF et coll 1968, SHABAD et coll 1974) Tumour manifestations occur late in the disease compared with the pleuroparenchymal fibrosis Chest radiography is used as the routine screening procedure to detect these lesions It has, however, been shown by regional isotope ventilation measurements that evidence of pulmonary-pleural disease may be present while conventional chest films appear normal (STANLEY 1975) In order to obtain the earliest possible indications of this disease and a more accurate assessment of the degree of involvement, 13 patients were examined by computer tomography on the EMI general purpose scanner

Material The patients referred were known to have been exposed to asbestos for intervals ranging from one to 40 years Chest films were available together with in-

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mit der verbesserten Konstruktion der Apparatur moglich sind, und eine hochentwickelte Rekonstruktionstechnik, konnen wahrscheinlich die gewhonlichen Rontgenbilder ersetzen

RESUMÉ

Les auteurs présentent leur expérience de la tomographie avec ordinateur du neurocrane sur 300 malades adressés pour tomographie avec ordinateur du cerveau. Les projections plus appropriées que permettent les Scanners de la 2ème génération et une technique de reconstruction élaborée paraissent remplacer les radiographies ordinaires du crâne



Fg 4



Fig 5

Fg 4 Calcif ed pleural plaques The larger plaque on the left diaphragm was seen on the chest f lm but not the smaller posterior plaques (→) There is also a fibrous band crossing the pleural cav ty from the larger calcif ed plaque on the left side WW = 400 WL = 0"0

F g 5 Asbestosis plaques on d aphragm below the level of the lungs (white arrow) as well as irregular d aphragm marg n over the l ver The r ght suprarenal gland (black arrow) is behind the infer or vena cava L = liver S = spleen K = kidney I = infer or vena cava A = aorta WW = 200 WL = +0"0

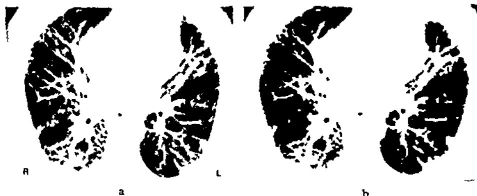


Fig 6 a) M ked h
regularities
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perfus on as

scribed as occurring in asbestosis (SOUTAR et coll 1974) These included pleural plaques subpleural and localised parenchymal infiltrates and fibrosis bulla formations and irregular pericardial and diaphragmatic adhesions or obliteration of the pleural sinuses In addition the presence of calcification was noted and attenuation measurements of the abnormal regions were made No contrast enhancement was used



Fig 1



Fig 2

Fig 1 Thin but extensive pleural plaque formation posteriorly (→) not visible on the conventional chest film WW (window width) 100 WL (window level) = 000

Fig 2 Pleural plaques in asbestosis visible posteriorly as well as along the lateral thoracic margin (→) The lateral pleural plaques were seen on the conventional chest film but not those paravertebrally WW = 200 WL + 020



Fig 3 Thick posterior pleural plaques (→) visible on the lateral chest film but not on the p a view Undulating right hemidiaphragm margin and thick bands close to the lateral margin of the spleen WW 400 WL = − 295

dependent reports of the findings These varied from normal to fine linear structures, grade S1/1 in mid and lower zones (UICC classification) Many cases had pleural plaques, some of which were calcified These cases were considered to be representative of early disease, radiologically ranging from normal to definite pleuro parenchymal involvement

Method Regions of possible disease were located from the chest films and between 5 and 8 selected tomographic sections were performed on the scanner These were arranged so that there should be at least one section in each of the three lung zones, as well as having a section at the dome of the diaphragm which would include the heart contour

Findings on the CT scans were compared with the abnormalities previously de-





Fig 11 Fig 12

Fig 11 Homogeneous lesion in the angle between the heart and the lesser fissure WW = 400 WL = −420

Fig 12. Marked irregularity of the diaphragmatic and cardiac margins on both sides, merging with the intrapulmonary lesions on the left On the chest film only the left sided abnormality adjacent to the heart was observed WW = 400 WL = −310



Fig 13 a) Normal lungs in a prone patient as seen on computer tomography with redistribution of pulmonary blood volume (light) to the anterior parts of the lungs With a person supine the gravity dependent posterior part of the lungs appears lighter instead WW = 200 WL = −405 b) With the section displayed at a low window width (at measure or 001) the greater perfusion in the gravity dependent parts of the lungs is readily appreciated WW = 001 WL = −365

plaques were present in 11/13 cases on the CT scans but were demonstrated in only 8/13 on the chest films

Mediastinal pleural irregularity

Marked irregularity, straightening or blurring of the cardiac margin, often continuing into a transpulmonary 'band' at the cardiophrenic angle, was observed in 5 of the subjects



Fig 7



Fig 8

Fig 7 Fine nodular structure especially on the right side On the left large confluent nodules in the periphery WW = 200 WL = −350

Fig 8 Homogeneous lesion on the right side apparently in or adjacent to the lesser fissure WW = 200 WL = 350

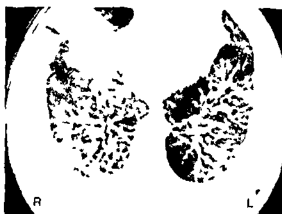


Fig 9

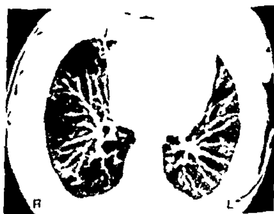


Fig 10

Fig 9 Marked subpleural irregular infiltrates on the right side (→) Marked diaphragmatic irregularity as well as haziness and irregularity of the cardiac contour, most evident on the left side Posteriorly on the right a honeycomb appearance of interstitial fibrosis is present and to a lesser extent on the left WW 400 WL 385

Fig 10 Thick 'band' across the right cardiophrenic angle (→) not visible on the chest film WW = 200 WL − 350

Pleural abnormalities

Plaques The appearance of pleural plaques and calcification on chest films is well known On CT scans these plaques may be uniform (Fig 1) and parallel to the thoracic wall or they may be irregular with varying thickness (Figs 2, 3) The innermost margin has a high attenuation zone which may be thin (Figs 1, 2) or quite thick (Fig 3) Calcification in the pleura is evident (Fig 4) These plaques may even extend along the crura of the diaphragm to a level well below the lungs (Fig 5) Pleural

Discussion

The radiologic signs of asbestosis indicating pleuropulmonary disease are well known It is recognized that the earliest abnormalities are those of small areas of pleural thickening Calcification in these pleural plaques occurs after many years Parenchymal disease is recognized as fine interstitial linear structures, straight or irregular and predominating at the bases

By regional ventilation measurements with ^{133}Xe it is possible to show that abnormalities may be present when conventional chest films are still normal (STANLEY 1976) Normal lung tissue has a marked gravity effect with increased perfusion in the dependent parts of the lungs, which is readily demonstrated on the CT scan, especially if displayed at a very narrow window width This normal gravity effect of increased perfusion was abolished in cases with asbestosis, which is probably a sign of interstitial fibrosis The reason for the loss of the gravity effect of perfusion is at the moment not known but is thought to represent some loss of the pulmonary capillary bed as a result of the interstitial fibrosis At present computer tomography is the only method available for the anatomic display of this phenomenon

CT scanning may also demonstrate pleural abnormalities, when chest radiography has been reported as normal In cases when disease is visible on the chest film the changes appear to be more extensive on the CT scan Regions of pleural thickening in the posterior sulcus are easily seen at computer tomography when the chest film may appear normal This also applies to the vascular abnormalities, the large transpulmonary 'bands' in the cardiophrenic and costophrenic angles, the mediastinal pleural thickening, subpleural irregularities and bulla formation In none of these cases did the chest film demonstrate abnormalities which could not be seen on the CT scan

Two features of particular interest are the coarse honeycomb appearance and the changes of pulmonary vessels On the chest film interstitial fibrosis appears as linear structures, either straight or irregular in the early phases, and with a honeycomb appearance in the late stages However, even when the chest film demonstrates the presence of thin linear structures, the appearance of the CT scan is that of a coarse honeycomb

One of the most obvious advantages of computer tomography is the clarity with which the pulmonary vessels can be seen without any contrast enhancement Consequently ...

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to ... show that fine and coarse nodular lesions occur

Finally, actual tissue attenuation measurements can be taken These may show a quite marked increase in pulmonary soft tissue attenuation up to 90 EMI ... greater than ...

whet ...

the fi ... be elucidated

Parenchymal abnormalities

Irregular honeycomb appearance In regions of thin linear structures (s in the UICC classification) as seen on chest films, the CT scan demonstrated large patches of honeycomb appearance with which the peripheral pulmonary vascular contours merged (Fig 6) Often these regions were subjacent to pleural plaques or regions of subpleural infiltrates and at measure setting no increased perfusion in the gravity dependent parts of the lung could be demonstrated (Fig 6 b)

Fine nodules Similar to p-structures in the UICC classification much finer, diffuse nodular abnormalities also occurred as well as larger confluent white nodular patches (Fig 7)

Lesser fissure abnormalities A large homogeneous region of high attenuation with irregular margins was found in 2 cases In both, this was on the right side and appeared to be adjacent to the lesser fissure (Figs 8, 11)

Subpleural infiltrates

These were demonstrated in 3 cases on the CT scans but could not be observed on conventional chest films In one cases it was most evident just above the right hemidiaphragm (Fig 9)

Bulla formation Regions with tissue attenuation approaching that of air were found in 2 cases These were considered to represent bulla formation

Peripheral pulmonary vessels Pulmonary vessels, which are tortuous and distended as well as abnormally thin and straightened, were noted in areas otherwise free of focal abnormalities These could not be observed on conventional films

Proximal pulmonary vessels In 2 cases the proximal pulmonary vessels were widened with abrupt tapering at the junction of the inner two thirds and outer one third of the lung

Loss of the normal increased perfusion due to gravity In the cases with parenchymal disease it was found that the normal effect of gravity causing increased perfusion (Fig 13) was abolished (Fig 6)

Transpulmonary 'bands'

At the cardiophrenic and costophrenic angles as well as on the diaphragmatic surface thick white 'bands' of soft tissue were seen in 3 cases on the scans (Figs 4, 10) No counterpart to these structures could be found on standard p a and lateral chest films The pathologic abnormalities causing this appearance are not known

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One of the most obvious advantages of computer tomography is the clarity with which the pulmonary vessels can be seen without any contrast enhancement Consequently, changes in size and shape of the pulmonary vascularity are easily appreciated These changes appear to be a major feature in parenchymal disease caused by asbestosis The scans also show that fine and coarse nodular lesions occur

Finally, actual tissue attenuation measurements can be taken These may show a quite marked increase in pulmonary soft tissue attenuation, up to 90 EMI units greater than normally encountered in lung tissue At present it is not possible to tell whether this is due to fibrosis or to the presence of the silicates It is hoped that in the future this point will be elucidated

SUMMARY

Thirteen individuals with varying lengths of exposure to asbestosis were examined by computer tomography with the EMI Scanner Various pleuroparenchymal abnormalities were found, *many not being seen on standard chest films In some cases, with normal chest* radiography, definite pleural involvement could be demonstrated, particularly that in the posterior sulci on the diaphragm and at the mediastinum Tissue attenuation measurements in regions of parenchymal involvement reached 90 EMI units above normal lung tissue The normal gravity effect is abolished in cases of parenchymal disease caused by asbestosis Parenchymal disease was much more obvious on the CT scans than on conventional chest films

ZUSAMMENFASSUNG

Dreizehn Personen mit unterschiedlich langer Asbestexposition wurden durch Computertomographie mit einem EMI-Scanner untersucht Es wurden verschiedene pleuroparenchymale Veränderungen gefunden, von denen viele nicht auf einem Standardrontgenfilm der Lunge zu sehen waren In einigen Fällen mit normalen Lungenrontgenbefunden konnte eine klare Pleurabeteiligung nachgewiesen werden, besonders in den hinteren Sulci des Diaphragmas und im Mediastinum Messungen der Gewebedichte des beteiligten Parenchyms erreichten 90 EMI-Einheiten uberhalb des normalen Lungengewebes Die normale Schwerkraft bewirkt dessen Verschwinden in Fallen einer parenchymatosen Erkrankung infolge Asbestose Parechymatose Erkrankungen sind wesentlich deutlicher auf CT Skans als auf einem konventionellen Lungenfilm

RÉSUMÉ

Treize sujets soumis a des expositions de longueur variable a l asbestose ont été examines par tomographie avec calculateur au moyen de l EMI Scanner L'auteur a trouve diverses anomalies pleuro-parenchymateuses dont beaucoup n'etaient pas visibles sur les radiographies thoraciques ordinaires Dans certains cas ou la radiographie thoracique etait normale, il a pu mettre en évidence des atteintes pleurales nettes, en particulier des atteintes des culs de sac diaphragmatiques posterieurs et du médiastin Les mesures d'attenuation par les tissus dans les regions d'atteinte parenchymateuse atteignaient 90 unités EMI au dessus du tissu pulmonaire normal L'effet de gravite normal est aboli en cas d atteinte parenchymateuse causee par l asbestose L'atteinte parenchymateuse est beaucoup plus evidente sur les images de tomographie avec calculateur que sur les radiographies simples du thorax

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DENSITOMETRIC EVALUATION OF LUNG AERATION IN CHEST FILMS

G ENHÖRNING and B ROBERTSON

In a previous report on lung expansion in newborn rabbits it was stated that a discrepancy existed between the radiographic impression of complete aeration of the lungs already within a few seconds after birth and the fact that histologic examination of the same lungs revealed comparatively large non-aerated areas persisting until the age of several hours (GROSSMANN et coll 1974) Since it was believed that this discordance could in part be due to failure of the eye to detect minor variations in film density, and since it was considered necessary to eliminate as far as possible any risk for biased interpretation in subsequent experimental work, a simple densitometric technique for evaluation of lung aeration in chest films was developed The present communication presents this technique as used in experiments on newborn rabbits, and its clinical application is suggested

Method

The technique requires a p projections of the chest, in rabbit neonates this condition was fulfilled by means of plexiglass holders (ENHÖRNING et coll 1975) For densitometry a binocular microscope was used in which a photocell had been substituted for one eyepiece The former increases its conductivity with illumination and forms one of the resistors in a Wheatstone bridge, the imbalance of which is amplified and recorded A slit, 1 mm wide and 2 mm long, placed just below the focal plane of the microscope, narrows the light beam from the condenser With a speed

This investigation was supported by the Canadian Medical Research Council (Grant No MA-4497) and the Swedish Medical Research Council (Projects Nos 12R-4183 and 60F-4183)
(B R. is now at the Department of Pathology, S t Gorans Sjukhus, S 112 81 Stockholm, Sweden)
Submitted for publication 1 September 1975



Chest film of two premature rabbit neonates. Litter mates delivered at the gestational age of 27 days (full term 31 days). Right: Well aerated lungs in a surfactant-treated animal; left: non-aerated lungs in control. To obtain the radiological expansion index (REI) the lungs are scanned between the two black markings and the attenuation of the radiation recorded.

of 24 mm per min, a synchronous motor moves the microscope stage, to which the film is attached, in a direction which is at right angles to the length of the light slit. With this arrangement, the films are scanned across the chest at the level of the 7th thoracic vertebra, between two black markings indicating the lateral margins of the lungs. The densitometer is calibrated against the background, which gives the baseline on the recording paper, and against a stepwedge included in each exposure (the Figure).

A *radiologic expansion index* (REI) is calculated using the formula

$$REI = \frac{2 \cdot R_{max}}{R_{left} + R_{right}}$$

R_{max} is the peak value (measured in mm above the baseline) in the tracing and reflects the attenuation in the central part of the chest where there is no lung tissue. R_{left} and R_{right} are values obtained from the tracing at points which are at a distance from the lateral markings corresponding to 10 per cent of the transverse diameter of the chest. At these points lung parenchyma is the only tissue within the chest walls which may influence the attenuation of the radiation.

... to rabbit neonates. The method was applied to a series of premature rabbi[ts], some of which had received a pharyngeal deposit of homologous lung [surfactant be]fore the first breath, a measure known to facilitate lung aeration in these [ani]mals (ENHÖRNING et coll. 1973 a). The results, reported in detail [...] et coll. 1975) are summarized in the Table.

Table

Radiologic expansion index in surfactant treated premature newborn rabbits and in untreated litter mate controls

Time after deposition procedure (min)	Radiologic expansion index ($\bar{X} \pm SD$)		p <
	Surfactant-treated (n = 26)	Controls (n = 23)	
0*	1 42 ± 0 16	1 25 ± 0 11	0 001
60	1 36 ± 0 17	1 23 ± 0 07	0 005
120	1 40 ± 0 14	1 23 ± 0 08	0 001

* i e immediately after deposition and subsequent first breath

Comment

Although our findings revealed a clear difference between surfactant-treated animals and controls, in neither group was there any variation in the REI with time This confirms the naked-eye impression gained from the same films (ENHÖRNING et coll 1975) It is also in accordance with previous microscopic observations in analogous experimental series of premature rabbit neonates, in the latter no correlation existed between the microscopically determined alveolar expansion index and the survival time (ENHÖRNING et coll 1973 b)

The miliary type of atelectasis ('of prematurity') which is characteristic of the respiratory distress syndrome, and which is known as 'reticulogranularity' of the lungs, was imitated by many of the rabbit fetuses in the series This particular appearance *is difficult* to quantitate objectively The trained radiologist will note it and *keep it in mind* as he evaluates lung aeration and the degree of respiratory distress syndrome present However, by necessity his grading will change with experience and with time Thereby, the radiologic evaluation of one institution will be difficult to *compare with* that of another; even within one institution the position of the 'grey zone' is not consistent By means of the densitometric technique presented, these *difficulties may* be avoided and lung aeration be assessed objectively and numerically

Admittedly, the present densitometric technique has some limitations It only evaluates lung [illegible] during the [illegible] ever, this w[illegible] affect the mean calculated from several exposures If densitometry were to be used clinically these limitations could easily be circumvented To obtain a more complete evaluation, the scanning could be performed at several levels and the results *combined* into one value The time of exposure could be standardized, for instance by recording respiratory movements and letting the peak inspiration trigger the exposure

SUMMARY

Lung aeration can be evaluated densitometrically from chest films, using a microscope with one eyepiece replaced by a photocell, and the attenuation of the pulmonary parenchyma can be assessed numerically, as a 'radiologic expansion index' In premature rabbit neonates this index was significantly increased among animals receiving a pharyngeal deposit of homologous lung surfactant before the first breath, as compared with untreated controls This technique could in modified form be used for clinical purposes, such as the evaluation of lung aeration in newborn infants with respiratory distress

ZUSAMMENFASSUNG

Der Luftgehalt der Lunge kann densitometrisch an Thoraxbildern unter Verwendung eines Mikroskops festgestellt werden, bei dem das eine Okkular durch eine Photozelle ersetzt ist, und die Abschwachung des Parenchyms der Lunge kann numerisch als ein rontgenologischer Expansionsindex bestimmt werden Bei pramaturen neugeborenen Kaninchen war der Index signifikant bei den Tieren erhoht denen homologes Lungen Surfactant im Pharynx vor dem ersten Atemzug deponiert worden war, verglichen mit unbehandelten Kontrollen Diese Technik konnte in modifizierter Form fur klinische Zwecke verwendet werden z B zur Feststellung des Luftgehalts der Lunge von neugeborenen Kindern mit einer Atemstorung

RESUME

L'aération pulmonaire peut etre évaluée par densitométrie a partir de radiographies pulmonaires, au moyen d un microscope dont un oculaire est remplacé par une cellule photoélectrique et l atténuation du parenchyme pulmonaire peut etre déterminee numériquement comme « indice d expansion radiologique » Chez des lapins nouveau nes prematurés cet indice est significativement augmenté chez les animaux dans le pharynx desquels on a déposé du surfactant pulmonaire homologue avant la première respiration par rapport aux sujets témoins non traités Cette technique pourrait sous une forme modifiée etre utilisée dans un but clinique tel que l évaluation de l aération pulmonaire chez les enfants nouveau nés qui ont une détresse respiratoire

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PULMONARY CONGESTION IN CHRONIC HEART DISEASE

Radiologic, clinical and hemodynamic relationships

P STAGE, B MOVILD, B HESSE and E STEINMETZ

The detection and the assessment of pulmonary vascular congestion are for routine purposes based on clinical and radiologic examination of the chest

The radiologic criteria have changed during recent years (MILNE 1973) More importance has been attached to the distribution of the pulmonary blood flow In acute cardiac failure caused by myocardial infarction it has been demonstrated that a redistribution of the blood flow to the upper lobes in the erect position is an early sign of failure (BENNETT & REES 1974, CHAIT et coll 1972, GROSSER et coll 1974, MCHUGH et coll 1972) In acute cardiac failure, radiology of the chest has been found to be a more sensitive indicator of failure than clinical signs (BENNETT & REES, CHAIT et coll GROSSER et coll, HARRISON et coll 1971, HULL et coll 1972, MCHUGH et coll) and a good relationship between the pressure in the pulmonary artery and the degree of failure, as evaluated radiologically, has been demonstrated (BENNETT & REES GROSSER et coll, MCHUGH et coll)

Several reports have appeared correlating hemodynamics with clinical and radio-

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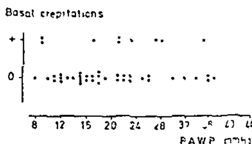


Fig 1 Crepitations on lung auscultation and pulmonary artery wedge pressures (PAWP) in 48 cases with chronic heart disease

logic indications of failure in chronic congestive heart failure The radiologic evaluation has been based mostly on measurements of the diameters of the pulmonary veins and arteries (FRIEDENBERG et coll 1966, SIMON 1964) Yet, in a reevaluation of chest films, flow redistribution was observed in practically all patients with critical mitral stenosis (SIMON 1972) A good relationship between the degree of *flow shift* and pulmonary venous pressure was also stated from the experience of more than 1 000 heart catheterizations (TURNER et coll 1972)

The main purpose of this report is to assess the value of routine roentgen examination of the chest in the evaluation of chronic congestive heart failure, on the basis of (1) *flow shift to the upper lobes, and* (2) *blurring of vessels in the lower lobes*, indicating pulmonary interstitial oedema In a prospective series of patients with chronic heart disease, lung auscultation, roentgen examination of the chest and pressures in the pulmonary circulation were compared

Material and Methods

The material consisted of 47 consecutive patients (age 16 to 71 years, mean 53, 28 females and 19 males) with chronic heart disease referred to the cardiovascular laboratory for cardiac catheterization Two patients were examined twice

Four patients belonged to functional class IV, one to class I, the remainder to class II or III (New York Heart Association) All but 4 were in treatment with digitalis drugs or diuretics, or both The cardiac diagnoses were Mitral or aortic valve disease, or both, in 41 (13 previously operated upon), cardiomyopathy in 3, ischemic heart disease in 2, and high output failure (extracardiac shunt) in 1

On the day before catheterization, clinical examination, including lung auscultation, was performed by the cardiologist, and diuretics were suspended

Next morning, immediately prior to catheterization, the patient was transferred in bed to the radiology department, postero-anterior and lateral chest films were taken in the erect position and one film in the right lateral decubitus projection Potter-Bucky diaphragm, 150 kV, and short exposure times were used, aiming at *hard penetrated films*

Right-sided cardiac catheterization was performed in local anaesthesia with antecubital venous surgical exposure The final evaluation of pulmonary congestion was

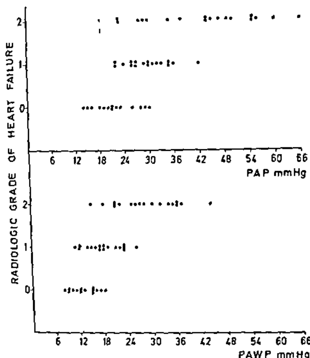


Fig 2 Radiologic grades of pulmonary congestion and pressures in the pulmonary circulation, pulmonary artery mean pressure (PAP) and pulmonary artery wedge pressure (PAWP) respectively, in 49 cases with chronic heart disease

based upon pressure recordings in the main pulmonary artery mean pulmonary artery pressure, PAP (normal <18 mmHg) and in the pulmonary artery wedge position mean pulmonary artery wedge pressure, PAWP (normal <12 mmHg)

Two radiologists, trained in cardiac radiology, evaluated the films without knowledge of clinical and hemodynamic findings In their grading of pulmonary congestion no efforts were made to differentiate between pulmonary veins and arteries, and the caliber of the vessels was not measured The grading was based on the subjective general impression of the flow distribution in the lungs (normal lower lobe vessels wider than upper lobe vessels in erect position) and the definition of lower lobe vessels (normal distinct outlines) Each examination was thus classified in one of three grades

Grade 0 Normal flow distribution and normal definition of vessels
Grade 1 Flow shift to upper lobes and normal definition of vessels
Grade 2 Flow shift to upper lobes and blurring of lower lobe vessels

In addition the presence of interlobular septa (Kerley's B-lines), pleural effusion and ill-defined infiltrates in the lungs indicating alveolar oedema were noted The heart volume was measured (JONSELL 1939) and expressed in m^2 of body area (normal females <450 ml/m^2, males <500 ml/m^2)

Table

Mean values and ranges of pulmonary artery wedge pressure (PAWP) and mean pulmonary artery pressure (PAP) in the 3 radiologic grades of pulmonary congestion P values refer to pressure differences between the 3 grades (Wilcoxon's rank sum test)

Roentgen grade of congestion	PAWP (mm Hg) Mean	PAWP (mm Hg) Range		PAP (mm Hg) Mean	PAP (mm Hg) Range	
0 (n = 14)	12 8	8–18	$p < 0.01$ (0 vs 1)	21 6	14–30	$p < 0.01$ (0 vs 1)
1 (n = 17)	18 1	11–26	$p < 0.01$ (1 vs 2)	29 8	22–42	$p < 0.01$ (1 vs 2)
2 (n = 18)	28 2	16–44		43 2	23–66	

Results

On lung auscultation, basal crepitations were heard in 9 patients (Fig 1), scattered at random over the scale of PAWP, with a mean value of 21 mmHg compared to 20 mmHg for the rest (Auscultation of the lungs was not performed in one patient) No difference was found between PAWP in the two groups ($p > 0.10$, Wilcoxon's rank sum test) A small pleural effusion, demonstrated radiologically in 10 patients, was not revealed by clinical examination in any case

The radiologic grade 0 was recorded in 14 patients, grade 1 in 17 patients and grade 2 in 18 patients The relationships between this grading and pressure recordings, PAWP and PAP, respectively, appear in Fig 2 The upper normal limits for the pressures are indicated It is evident that there is a distinct relationship between the radiologic appearances and the pressures, though there are no distinct limits between the 3 radiologic grades Thus grade 0 (normal flow distribution) was associated with both normal and slightly increased pressures, grade 1 and 2 (flow redistribution) with increased pressures, but grade 1 with both slightly and moderately increased pressures and grade 2 with both moderately and markedly increased pressures Anyhow, significant differences in PAWP and PAP in the 3 grades were found by Wilcoxon's rank sum test for 2 samples (Table)

Additional findings Interlobular septa were demonstrated only when PAWP was 18 mmHg or more, of 27 patients with higher pressures septa were found in 14

A small pleural effusion was demonstrated in 10 patients, in 4 only in the lateral decubitus position Pleural effusion was demonstrated only when PAWP was 21 mmHg or more, of 22 patients with higher pressures effusion was found in 10

Alveolar oedema was demonstrated only when PAWP was 30 mmHg or more, of 8 patients with higher pressures alveolar oedema was found in 4

The relative heart volume, *in ml per m² body area, ranged in group* 0 from 390 to 780 (mean 595), in group 1 from 570 to 1 335 (mean 776) and in group 2 from 435 to

1 335 (mean 770) Four patients had no enlargement of the heart, 2 in group 0 and 2 in group 2 The relative heart volumes were found significantly smaller in group 0 than in groups 1 and 2 ($p < 0.01$), without significant difference between the latter groups ($p > 0.1$) (Wilcoxon's rank sum test)

Discussion

In the evaluation of pulmonary congestion PAWP and PAP were employed PAWP is usually identical with left atrial pressure and is considered the most important factor in the development of pulmonary oedema in heart failure Also PAP can be used as an indicator of left atrial pressure, provided the pulmonary vascular resistance is not severely increased In the present material only 5 patients, all of grade 2, had vascular resistance exceeding 500 dyn s cm^{-5}, and as would be expected nearly the same relationships were found between the radiologic grade of pulmonary congestion and PAWP and PAP, respectively (Fig 2, Table)

The basal crepitations recorded in patients with pulmonary congestion are usually heard only during inspiration Thus they are not likely to be caused by free fluid in the alveoli, but are presumably due to interstitial oedema producing a delayed opening of the airways

In the present investigation no relationship was found between the results from auscultation and PAWP This finding supports the concept that auscultation is insufficient to demonstrate interstitial pulmonary oedema, slight alveolar oedema and slight pleural effusion (HULL et coll)

In acute cardiac failure roentgen examination of the chest has to be performed in the bed with the patient in a semirecumbent position (BENNETT & REES, CHAIT et coll , GROSSER et coll , HARRISON et coll , HULL et coll , MCHUGH et coll) In the present material of patients with chronic heart disease a more favourable roentgen technique could be employed As a routine hard penetrated films were applied By this technique the pulmonary vessels of the lower lobes were well demonstrated, while the upper lobes were often overpenetrated This caused in a few cases difficulty in distinguishing between *slight flow* redistribution (grade 1) and normal flow distribution (grade 0) A flow shift was best demonstrated in the right lateral decubitus projection in 8 cases, dilated vessels in the elevated left lung and constricted vessels in the right This projection was always superior for the demonstration of small pleural effusions, especially if a subcostal fat layer was present

In daily routine the radiologic evaluation of heart failure and [illegible]

[illegible] a more graduated evaluation was possible when additional indications of *cardiac failure* were taken into consideration, especially the appearance of interlobular septa, pleural effusion and alveolar oedema With increasing

PAWP the sequence of appearance of the radiologic abnormalities was (1) flow shift, (2) blurring of vessels in the lower lobes, (3) interlobular septa, (4) pleural effusion, and (5) alveolar oedema This sequence has also been noted in acute cardiac failure (BENNETT & RELS, GROSSER et coll , MCHUGH et coll)

By means of the 2 first mentioned criteria, it was possible to distinguish three groups of patients with statistically different pulmonary arterial pressures In acute cardiac failure, similar significant differences have only been demonstrated between normal vessels and isolated flow shift (grade 0 and 1), not between isolated flow shift and interstitial oedema (grade 1 and 2) (GROSSER et coll)

Some patients in the radiologic group 0 had slightly elevated pressures and similarly some patients in group 1 had pressure values, which would usually indicate interstitial oedema (Fig 2) Thus, the pressures were slightly underestimated The underestimation by flow shift could be caused by lower pressures in the erect position (roentgen examination) than in the recumbent position (pressure recordings) The underestimation by blurring of lower lobe vessels could be caused by a 'post therapeutic phase-lag' Diuretics were suspended the day before roentgen examination and cardiac catheterization It is known, that a change in the PAWP as caused by suspension of diuretics may precede clinical and radiologic changes by many hours (BENNETT & RELS, GROSSER et coll , MCHUGH et coll)

The size of the heart *was found of little value in the radiologic evaluation of* pulmonary congestion

Elevation of the diaphragm, which could be caused by diminished lung compliance, was not employed as an indication of congestive failure It was also considered too *unspecific, especially in single examinations*

The present results of radiologic grading of pulmonary congestion in chronic heart disease are generally in accordance with those reported in acute cardiac failure (BENNETT & RELS, GROSSER et coll , MCHUGH et coll)

Scintigraphy has been used to record the blood flow distribution in the lungs in mitral valve disease (SIMON et coll 1973) Flow shift was recorded in most patients, but the correlation between the degree of shift and hemodynamic recordings were not significant

In contrast to the reported findings in acute failure, a high frequency of interlobular septa and a low frequency of pulmonary alveolar oedema in spite of high pressures were found In chronic heart disease abnormal septa were found in 50 per cent of patients with PAWP higher than 18 mmHg, compared to less than 10 per cent in acute failure Pulmonary alveolar oedema, demonstrated by ill-defined infiltrates in the lower lobes, was *found in only 4 of 8 patients with* PAWP *higher* than 30 mmHg This absence of alveolar oedema in chronic heart disease has been attributed to increased lymphatic return and to intraalveolar fibrosis, caused by organisation of fibrinous oedema, reducing the permeability of the alveoli (HEARD et coll *1968*)

SUMMARY

Pulmonary congestion in chronic heart disease was evaluated by lung auscultation and roentgen examination of the chest and compared with pressure recording of the pulmonary circulation in 49 cases Whereas auscultation appeared not to be correlated to the pressures, the radiologic findings proved to be a reliable measure of increased pressures The radiologic assessment was based on isolated flow shift to the upper lobes of the lungs, indicating slight pulmonary venous hypertension, and flow shift in association with blurring of the lower lobe vessels indicating pulmonary interstitial oedema In distinction to the results from acute cardiac failure interlobular septa were often demonstrated in association with pulmonary interstitial oedema, and pulmonary alveolar oedema rarely demonstrated in spite of marked pulmonary venous hypertension

ZUSAMMENFASSUNG

Die Stase der Lunge bei chronischer Herzerkrankung wurde durch Auskultation und Rontgenuntersuchung beurteilt und mit den Druckbestimmungen im Lungenkreislauf bei 49 Fällen verglichen Wahrend die Auskultation nicht zum Druck korreliert zu sein scheint, erwiesen sich die rontgenologischen Befunde als zuverlassiges Mass des erhohten Druckes Die rontgenologische Beurteilung stutzte sich auf die isolierte Durchflussänderung zu den oberen L

venose Hypertension anzeigt, und

efässe des unteren Lungenlappens,

Gegensatz zu den Ergebnissen bei einem akuten Herzversagen wurden die interlobularen Septen im Zusammenhang mit einem *interstitiellen Lungenodem* oft dargestellt dagegen selten ein alveolares Ödem trotz einer kraftigen pulmonalen venosen *Hypertension*

RÉSUMÉ

La congestion pulmonaire dans les cardiopathies chroniques a ete évaluee par l auscultation pulmonaire et par l examen radiologique du thorax et a eté comparee avec les enregistrements de pression de la circulation pulmonaire dans 49 cas Alors que l auscultation ne parait pas en rapport avec les pressions, les signes radiologiques se revèlent etre une mesure fidéle de l augmentation des pressions Le diagnostic radiologique est basé sur le deplacement isole de la circulation vers les lobes superieurs des poumons indiquant une legere hypertension veineuse pulmonaire et un deplacement de la circulation associé a ... vaisse...

... mis en evidence malgré une hypertension veineuse pulmonaire marquée

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VISIBILITY OF THE INTRAPERICARDIAC SEGMENT OF THE ASCENDING AORTA ON CONVENTIONAL LATERAL CHEST FILMS

G BERGSTRAND and A SZAMOSI

The intrapericardiac segment of the ascending aorta may conveniently be divided into an intracardiac and an extracardiac part The lowermost segment of the aorta, consisting of the short intracardiac part and a variable length of the extracardiac part, is not usually surrounded by aerated lung tissue, it is, therefore, difficult to discern on conventional films (VIAMONTE et coll 1975) Descriptions of the normal appearance are scarce, except when the wall is calcified, or when angiography is performed However, one of us has observed that, on many occasions, this part of the ascending aorta can be discerned on the lateral chest film of adults, even in the absence of any visible calcification In a few cases the finding could be confirmed at subsequent angiography As the possibility of localizing the aortic ostium within the heart [illegible]

[illegible] aorta) is visible on conventional lateral chest films of adults

Material and Methods

The lateral chest films of 284 randomly selected patients were reviewed Films with visible calcifications anywhere in the wall of the thoracic aorta were not included

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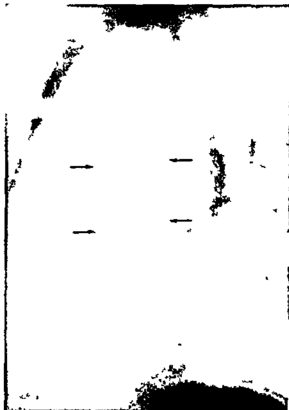


Fig 1

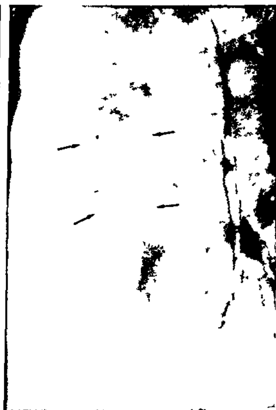


Fig 2

Fig 1 Lateral film The anterior and posterior outlines of the ascending aorta (→) are evident

Fig 2 Male, aged 22 The ascending aorta is visible

All patients were referred for examination in the course of a routine check-up, i e none of them had any clinical or radiologic signs of heart disease No extra films were obtained specially for the present inquiry The relevant technical data in the exposure and processing of the films were the following Tube potential 180 kV, FFD 200 cm, Kodak Medical X-Ray films RP/L and Kodak X-omatic intensifying screens were used, and a Kodak RP X-omat apparatus utilising RP MX 810 developer at 35 5°C, processing time 90 s The film stand was equipped with a non-moving focussed grid, 100 lines per 2 54 cm (1 inch) with a ratio of 1 12 Typical exposure times were 10 to 25 ms for the lateral films

The films were scrutinised for the visibility of the aorta and the material was then divided into three groups Cases where the aorta could not be discerned at all were referred to group A Those cases in which either the anterior or posterior outlines of the aorta could be observed were referred to group B, together with those in which

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Fig 5 Rheumatic mitral stenosis The calcification in the anterior mitral leaflet (confirmed at cineangiography) is projected somewhat in front of the posterior aortic wall *The sagittal diameter* of the left atrium can be estimated by measuring the distance (↔) between the posterior aortic wall and the posterior outline of the left atrium (a) or the contrast filled oesophagus (b)

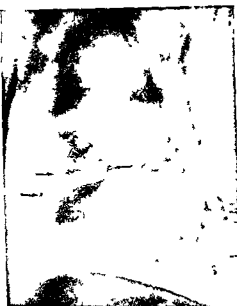


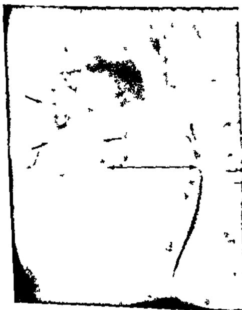
Fig 3



Fig 4

Fig 3 Intracardiac calcifications (→) around the aortic orifice (Subsequent cineradiography demonstrated the calcifications to belong to the coronary arteries)

Fig 4 Calcified aortic valve stenosis The granular calcification (→) is localised within the outlines of the aorta Fusiform dilatation of the middle part of the aorta Narrow area of diminished attenuation around the aortic wall



a



b

Fig 5 (For legend see opposite page)

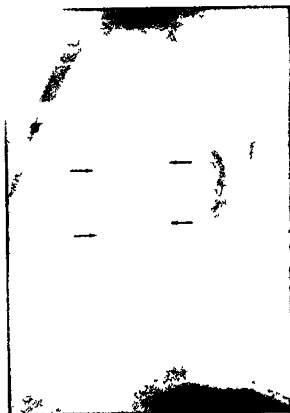


Fig 1

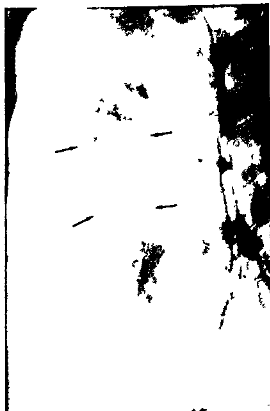


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Table

Frequency with which the ascending aorta is visible on lateral chest films

Age group (years)	Number of patients			
	Group A (no visibility)	Group B (one border or band of increased attenuation visible)	Group C (anterior and posterior border visible)	Total
20-40	67 (80 %)	13 (15 %)	4 (5 %)	84 (100 %)
40-60	45 (34 %)	62 (47 %)	25 (19 %)	132 (100 %)
>60	21 (31 %)	28 (41 %)	19 (28 %)	68 (100 %)
Total	133 (47 %)	103 (36 %)	48 (17 %)	284 (100 %)

tenuation than the surroundings in general, within the outlines of the heart (only Figs 1 and 2 belong to the normal material represented in the Table) Both phenomena were sometimes combined (Fig 7)

Discussion

The radiologic contrast between the aorta and its surroundings, if any, must be very low The maximum permissible level of blurring and minimum level of contrast necessary for the perception of an object varies between different observers So does film contrast and the blurring of detail in films from various departments Therefore, such frequency figures as given in the Table obviously depend on a number of factors which are partly subjective and partly accidental It is, however, quite clear that, in adults, the aorta surprisingly often is visible within the outlines of the heart Before considering the clinical significance of this finding a few well established facts about cardiac anatomy should be recalled

The ascending aorta arising from the left ventricle is bordered anteriorly to the left by the right ventricle and, anteriorly to the right by the right auricle Posteriorly, the aorta is located in front of and adjacent to the left atrium, and above this, to the right pulmonary artery The posterior wall of the aorta is continuous with the anterior leaflet of the mitral valve

From these anatomic relationships the following conclusions may be drawn First, whenever the lowermost part of the aorta is discernible on the lateral chest film, the aortic ostium can be localised fairly exactly This permits the localisation of cardiac calcifications in relation to the ostium (Figs 3, 4) Secondly, by following the posterior outlines of the aorta it is possible to estimate the position of the anterior mitral leaflet (Fig 5) By the same token, the posterior wall of the aorta indicates the position of the anterior wall of the left atrium, provided that the heart is not rotated and the atrium itself is of normal size or only moderately enlarged The depth of the left atrium can then be estimated by measuring the distance between



Fig 6

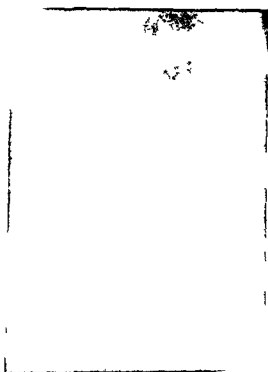


Fig 7

Fig 6 Aortic insufficiency of moderate severity General dilatation of the aorta

Fig 7 Aortic regurgitation developing on the basis of a dissecting aneurysm The anterior outline of the aorta is evident

the position of the aorta was marked by a band-like area, differing in attenuation from the surroundings, rather than by sharp outlines Lastly, cases where both the anterior and posterior walls could be observed on a continuous segment of at least 1 5 cm length, were referred to group C Further subdivisions were made according to the age of the patients

Results

The frequency with which the aorta was visible in the various age groups appear in the Table In somewhat more than half of the cases it was possible at least to determine the position of the aorta Not infrequently it was possible to discern the outlines both anteriorly and posteriorly (Fig 1) Sometimes the aorta was visible even in young adults (Fig 2) However, there was a marked positive correlation between the visibility of the aorta and the age of the patient When several films belonging to the same patient were compared, great differences in the visibility of the aorta were common, irrespective of whether the comparison was made with a previous examination or with a repeat film on the same day Sometimes the aorta appeared to be surrounded by a narrow band-like area of lesser attenuation (Fig 4) In other cases the image of the aorta seemed to consist of an area of somewhat greater at-

the posterior aortic wall and the contrast filled oesophagus, or, preferably, by the posterior left atrial wall itself In this way the distinction between the normal and enlarged atrium could be made more accurate (Fig 5) Thirdly, the observation of the width and shape of the aorta can be helpful in distinguishing between primarily valvar disease with secondary dilatation of the aortic wall on the one hand, and primary aortic wall disease on the other In typical aortic valve stenosis a fusiform dilatation of the middle portion of the aorta is usually found, while the aortic root remains of normal size Widespread loss of the elastic components in its wall causes a more or less uniform dilatation of the aorta (Fig 6) In cases of cystic medial necrosis and other types of aneurysms there is often a marked club shaped widening of the aortic root while the other segments may or may not be dilated This distinction between aortic valve and aortic wall diseases is the more important as the clinical and auscultatory findings are sometimes confusing in the latter group, e g aortic insufficiency developing on basis of a dissecting aneurysm (Fig 7)

The reason why the aorta is visible at all on lateral chest films is not fully understood Any attempt to explain it should take several possible factors into consideration It may be assumed that the heart and pericardium provide for slight local differences in attenuation of the radiation Under particularly favourable circumstances, a film contrast as low as 0 005 per cent, corresponding to an object contrast of about 2 per cent, can be diagnostically useful (TER-POGOSSIAN et coll 1974) The lower attenuation around the aorta suggests the presence of loose or fatty tissue This may be seen either as a narrow sheath surrounding the lowermost segment, or as a more homogeneous, larger area within which the upper part of the aorta is visible When there is only a small amount of pericardial fat, the uppermost part of the ascending aorta, still inside the pericardial sac, stands out against aerated lung tissue This will often happen when the aorta is dilated (Fig 8) or the lung is hyperinflated, because the curved surface separating the two structures will, at some point, be tangentially oriented with respect to the central beam The aortic annulus, and with it the lower part of the aorta, is moving phasically, in a rather complex pattern, with every heart beat (MERCER 1969) The small contrast differences that might be present at this level will, therefore, often be blurred out The relative importance of the various factors which separately or together make possible the detection of the lower ascending aorta has not been determined in this investigation Besides the anatomic peculiarities such as the amount of fat in the tissue present around the aorta of the individual patient, a short exposure time seems critical

SUMMARY

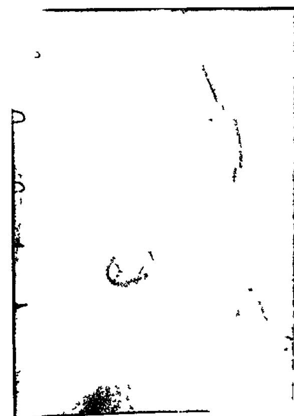
In a retrospective survey of the lateral chest films of 284 adult patients the intrapericardiac part of the ascending aorta was at least partly discernible in more than half of the cases, those with visible calcifications in the aortic wall were excluded None of the patients had known heart disease When the intrapericardiac part of the ascending aorta is visible it can



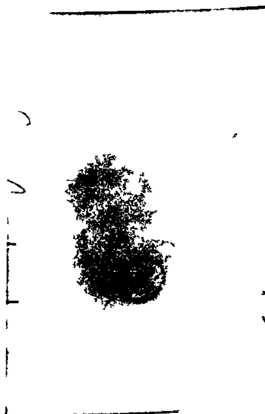
a



b



c



d

ʳ dissecting aneurysm from the incision used for
ɪle part of the dilated aorta bulges markedly into

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IONIC COMPOSITION AND CARDIOTOXICITY OF DIMERIC CONTRAST MEDIA AT INJECTION INTO THE CORONARY ARTERIES OF RABBITS

A M CARTER and T OLIN

The highly concentrated solutions of contrast media currently used for angiography are strongly hypertonic, which is one reason for their toxicity One way to achieve the desirable reduction of tonicity, without a corresponding reduction in iodine content, is to polymerize the conventional anions (HILAL 1966) Two of the dimers developed with these considerations in mind, iozomate (BJÖRK et coll 1969), and iocarmate (BAUMGARTNER et coll 1970) have hitherto been used only as meglumine salts It seemed unlikely that these salts would prove suitable for use in the coronary circulation since experience with monomeric contrast media has shown that those without a sufficient content of sodium ions are particularly apt to precipitate ventricular fibrillation (SNYDER et coll 1971) There is nevertheless disagreement as to the optimum sodium content of a contrast medium intended for coronary angiography (PAULIN & ADAMS 1971, SNYDER et coll 1971) and previously it was found to vary both with the nature of the anion and in relation to the other cations present (CARTER & OLIN 1975) Therefore, an attempt has been made to establish a suitable cationic composition for each of the two dimeric contrast media by testing various mixtures of their sodium and meglumine salts in the coronary circulation of the rabbit

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be clinically useful for the localisation of intracardiac calcifications in relation to the aortic orifice (inside or outside), for estimating the sagittal diameter of the left atrium and for evaluating the width and shape of the aortic root

ZUSAMMENFASSUNG

Bei einer retrospektiven Durchsicht der seitlichen Thoraxfilme von 284 erwachsenen Patienten war der intraperikardiale Teil der Aorta ascendens bei wenigstens der Hälfte der Fälle unterscheidbar Die Fälle mit sichtbaren Verkalkungen der Aortawand wurden ausgeschlossen Keiner hatte bekannte Herzerkrankungen Wenn der intraperikardiale Teil der Aorta ascendens sichtbar ist, kann dieser klinisch zur Lokalisation intrakardialer Verkalkungen in Relation zur Öffnung der Aorta (der inneren oder äusseren), zur Bestimmung des sagittalen Durchmessers des linken Vorhofs und zur Feststellung der Weite und Form der Aortawurzel verwendbar sein

RÉSUMÉ

Dans une étude rétrospective des radiographies de profil du thorax de 284 patients adultes, la partie intra-péricardique de l'aorte ascendante a été au moins en partie visible dans plus de la moitié des cas Les cas ayant des calcifications visibles de la paroi aortique ont été exclus de cette étude Aucun malade n'avait de maladie cardiaque connue Quand la partie intra-péricardique de l'aorte ascendante est visible elle peut avoir un intéret clinique pour la localisation des calcifications intra-cardiaques par rapport à l'orifice àortique (à l'intérieur ou à l'extérieur de cet orifice) pour estimer le diamètre sagittal de l oreillette gauche et pour apprécier la largeur et la forme de l'origine de l'aorte

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and the left hindlimb for ECG registration (Lead II) A polyethylene catheter (OD/ID=0 65/0 25 mm) was introduced via the right common carotid artery With the aid of magnification fluoroscopy, its finely tapered tip could alternately be inserted into the left or the right coronary artery as often as desired (CARTER & OLIN 1973)

The contrast media tested were based on the sodium and meglumine salts of iocarmic acid (Guerbet, France) and iozomic acid (Pharmacia, Sweden) Meglumine iocarmate is commercially available as Dimer-X and meglumine iozomate has been tested clinically under the code name PhDZ 59B The concentration of iocarmate and iozomate ions in the solutions supplied was 840 mmol/l and 867 mmol/l, respectively, corresponding to iodine contents of 320 mg/ml and 310 mg/ml Since considerable individual variations in the reaction to coronary arterial injection of contrast media exist, only comparisons of reactions obtained in the same animal were considered valid Furthermore, no more than three mixtures were tested on each animal in order to minimize interaction The doses were 0 4, 0 6 and 0 9 ml The procedure was as follows First, 0 4 ml of each mixture was injected into the left coronary artery A pause was interposed between each injection and was increased if adverse reactions occurred The catheter tip was then turned to the right coronary artery for injection of the 0 4 ml dose on this side The catheter tip was then re-inserted into the left coronary artery and 0 6 ml of each mixture injected In this manner increasing doses, from 0 4 to 0 9 ml, were injected alternately into the left and the right coronary arteries

Ventricular fibrillation, when provoked by an injection, was often of short duration, and a normal sinus rhythm was resumed spontaneously within a few seconds Otherwise, external heart massage was given and usually effectively promoted defibrillation If irreversible changes occurred, either in the ECG or in the arterial blood pressure, the experiment was discontinued

Results

Evaluation of the iocarmate mixtures proceeded stepwise (Table 1) In the first experiment, the pure meglumine salt was tested and caused ventricular fibrillation in a dose of only 0 4 ml at injection into both the right and the left coronary arteries In the four subsequent experiments, however, the least severe toxic reactions were obtained with the mixture containing least sodium, 210 mmol/l In the final 4 experiments all the mixtures tested had a relatively low sodium content Those containing 263 and 315 mmol/l proved to be least toxic, but even they evoked several arrhythmias, especially at injection into the right coronary artery

The iozomate salts were tested in the same fashion, with successive modifications in the composition of the contrast medium (Table 2) The pure meglumine salt evoked ventricular fibrillation in a dose of 0 6 ml when injected into the left or the right coronary artery The second and third experiments demonstrated the relatively

Table 1

Cardiac arrhythmias evoked by selective injection into the coronary arteries of contrast media containing sodium and meglumine iocarmate

Sodium content mmol/l	Left artery 0 9	0 6	0 4 ml	Right artery 0 4	0 6	0 9 ml
840		—	—	ES	VF	
420		—	—	—	HB + ES	
0		HB + ES	VF	VF	VF	
630	—	es	—	—	—	VF
420	es	es	—	—	es	ES
210	—	—	—	—	es	VF
630	VF	VF	VF	—	HB + es	HB + ES
420	ES	—	—	—	HB	HB + ES
210	—	—	—	—	HB	VF
420	—	—	—	ES	es	es
315	—	—	—	ES	ES	—
210	—	—	—	—	—	—
420	—	—	—	ES	VF	VF
315	—	—	—	es	es	ES
210	—	es	—	—	es	es
263	VF	—	—	—	—	
210		—	—	VF	VF	
158		—	—	VF	VF	
263			—	—		
210			—	—		
158			—	VF		
315	—	—	—	—	—	ES
263	es	—	—	—	HB ES	VF
210	HB	—	—	VF	VF	VF
315	—	—	es	—	ES	VF
263	ES	—	—	—	es	VF
210	—	HB	—	VF	VF	VF

es = single extrasystoles, ES – sequence of 2 to 5 extrasystoles, VF ventricular fibrillation or 5 extrasystoles, HB = second degree or complete heart block arrhythmia absent or minimal Gaps appear in experiments, which were terminated due to irreversible changes in cardiac function or terminal ventricular fibrillation

Material and Methods

Fourteen animals were used General anaesthesia was obtained with intravenous pentobarbito

recording of

dimers, iozomate and iocarmate The experiments were pursued with successive modification of the salt composition, until an appropriate sodium concentration was established for each contrast medium

In experiments of this type, it is important to bear in mind that interaction may occur Thus the response to a given injection of contrast medium may be modified by the residual effects of previous injections in a sequence GUZMAN & WEST (1959) reported that the effect of coronary arterial injections of contrast medium on the ECG of dogs diminished following repeated injections Table 1 reveals a systematic variation in response to the iocarmate mixture containing 210 mmol/l sodium, which may be ascribable to interaction This mixture seemed to be of low toxicity in experiments that included mixtures with a high sodium content yet relatively toxic in tests where such mixtures were excluded Some protection against the mixture containing 210 mmol/l sodium may have been afforded by the prior injection of a contrast medium containing a high concentration of sodium

In the least toxic mixtures of sodium and meglumine salts, the sodium concentration was 263 to 315 mmol/l for iocarmic acid and 271 to 379 mmol/l for iozomic acid In the previous report on monomeric contrast media (CARTER & OLIN 1975), the least toxic products tested were composed of the sodium and meglumine salts of diatrizoate (Urografin 76 %) and iothalamate (Vascoray = Cardio-Conray), and with a sodium content of 159 and 409 mmol/l, respectively These findings are not consistent with the view (PAULIN & ADAMS 1971) that the sodium content of a contrast medium ought to be close to the physiologic level, i e 140 mmol/l The present results rather support the conclusion (CARTER & OLIN 1975) that it is not possible to state the optimum sodium concentration for any contrast medium without taking into account the other ions present When a new anion is under consideration for use in the coronary circulation the most suitable salt composition of the contrast medium must be established by trial and error The present procedure can meaningfully be employed to this end

SUMMARY

The relation between ionic composition and cardiotoxicity of two dimers, iocarmate and iozomate was investigated by selective injection into the left and right coronary arteries Least toxic reactions developed at a sodium concentration of 263 to 315 mmol/l for sodium meglumine iocarmate and 271 to 379 mmol/l for sodium meglumine iozomate

ZUSAMMENFASSUNG

Die Relation zwischen der Jonenzusammensetzung und der Herztoxizitat von zwei Dimeren Iocarmat und Iozomat, mittels selektiver Injektion in die linke und rechte A coronaris wurde untersucht Die geringsten toxischen Reaktionen traten bei einer Natriumkonzentration von 263 bis 315 mmol/l fur Natrium Meglumin Iocarmat und von 271 bis 379 mmol/l fur Natrium–Meglumin Iozomat auf

Table 2

Cardiac arrhythmia evoked by selective injection into the coronary arteries of contrast media containing sodium and meglumine iozomate

Sodium content mmol/l	Left artery 0 9	0 6	0 4 ml	Right artery 0 4	0 6	0 9 ml
867		HB	—	—	ES	
434		es	—	—	VF	
0		VF	—	—	VF	
650	ES	VF	ES	—	VF	VF
434	VF	es	—	—	VF	VF
217	—	ES	—	—	—	—
325	—	—	—	—	—	—
217	VF	ES	—	—	—	VF
108	VF	HB + es	—	VF	VF	VF
379	ES	—	—	—	—	—
325	ES	—	—	—	—	—
271	ES	—	—	-	-	—
379	—	—	—	—	-	—
325	—	—	—	—	es	—
271	—	—	—	—	—	—

Abbreviations as in Table 1

great toxicity of mixtures with, respectively, a high or a very low sodium content Finally the sodium concentration was decreased to between 271 and 379 mmol/l, a range within which few toxic reactions were observed

Discussion

The cardiotoxicity of contrast media of varying composition is frequently evaluated in the Langendorff preparation (SALVESEN et coll 1967, ALMEN 1973) One disadvantage of this technique is that it involves non-selective administration of the contrast medium to the coronary circulation It is known that flooding the aortic root with contrast medium causes less change in the ECG than does selective coronary injection (MACALPIN et coll 1966) Furthermore, cardiac arrhythmia frequently arises due to regional differences in conduction velocity and these are more likely to occur when only one half of the coronary circulation is perfused with contrast medium With these considerations in mind, a technique for selective catheterization of the right and left coronary arteries of the rabbit was developed (CARTER & OLIN 1973) and it was used to compare commercially available, monomeric contrast media (CARTER & OLIN 1975) The same technique has now been applied to evaluate the cardiotoxicity of contrast media based on the sodium and meglumine salts of two

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EFFECTS ON VENOUS VASOMOTION FROM THE IONIC CONTENT OF CONTRAST AGENT SOLUTIONS

An investigation on microcirculation in the bat wing

TORSTEN ALMÉN

It has been shown that several of the effects on microcirculation from topical application of water soluble contrast media are related to their hypertonicity (ALMÉN & WIEDEMAN 1968) These effects include the stopping of spontaneous contractile activity of veins and lymphatic vessels and also the formation of intravascular aggregates of red blood cells which decrease the blood flow

The synthesis of metrizamide and other non ionic iodine compounds (Nyegaard & Co) has resulted in water soluble contrast media for which the factor osmolality/iodine content has been markedly reduced Topical application of some of these new compounds to the blood vessels of the bat wing has confirmed their reduced osmotic effects on microcirculation when compared in iodine equivalent concentration with some of the currently available modern ionic contrast media (ALMÉN 1973) As a consequence of these findings the new contrast media deserve attention for different angiographic purposes

For a short period during an angiographic procedure a bolus of contrast medium will flow through the vessels instead of blood When injected selectively into an artery the medium will exert local effects in the organ supplied by this vessel Such

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RÉSUMÉ

La relation entre la composition ionique et la cardio toxicité de deux dimères, l iocarmate et l'iozomate, a été étudiée par l'injection sélective dans les artères coronaires gauche et droite Les réactions toxiques les plus faibles sont obtenues avec une concentration en sodium de 263 à 315 mmol/l pour l'iocarmate de sodium méglumine et de 271 à 379 mmol/l pour l'iozomate de sodium-méglumine

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were performed in random order and the effects on venous vasomotion at varying time of application were registered

The values of osmolality given in the tables have been approximated from values obtained during previous measurements of different contrast agent solutions, based on determinations of freezing point depression or vapor pressure

The buffered saline used had the following composition

$$Na^+ \ 115 \text{ mEq/l}, K^+ \ 6.2 \text{ mEq/l}, Ca^{++} \ 1 \text{ mEq/l}, Mg^{++} \ 2 \text{ mEq/l},$$
$$Cl^- \ 122.2 \text{ mEq/l}, H_2PO_4^- \ 1 \text{ mEq/l and } HCO_3^- \ 1 \text{ mEq/l}$$

The expressions 'physiologic cations' and 'physiologic anions' refer to the ions in buffered saline

Effects of solutions not containing physiologic cations and anions

In 10 experiments buffered saline was applied topically on the veins and in all these experiments no effect on the contractile activity of the veins appeared during an application time of one hour In 3 of the experiments the time of application was extended to 24 hours and the veins were still contracting

Some test solutions of the same osmolality as buffered saline (0 25 osm) were also applied on the veins None of these solutions contained any of the ions in buffered saline These test solutions were

1) Meglumine metrizoate, an ionic contrast medium, containing 50 mg I/ml at an osmolality of about 0 26 osm
2) Metrizamide, a non-ionic contrast medium, containing 150 mg I/ml at an osmolality of about 0 24 osm
3) Glucose, containing no iodine and no ions Osmolality about 0 25 osm

All these test solutions stopped the spontaneous contractile activity of the veins within 5 to 10 min The results of the individual experiments appear in Table 1

Discussion and Conclusion All the solutions tested had the same osmolality All solutions which stopped venomotion did not contain any of the ions present in buffered saline Therefore, it is possible that the effects on vasomotion from the meglumine metrizoate, metrizamide and glucose solutions could be related to the absence in these solutions of one or several of the ions in buffered saline

There are at least two factors involved in the mechanisms through which contrast agent solutions may stop venous vasomotion (1) high osmolality (hypertonicity), and (2) absence of ions which are essential for venomotion

As such ions contribute to the osmotic effects of a contrast agent solution, it is of particular interest to investigate whether some of the ions in buffered saline are more important than others for the maintenance of normal venomotor activity Then it might be advantageous to add only these ions to a contrast agent solution in order to keep the osmotic effects as low as possible Further experiments were therefore

local effects of an angiographic contrast medium may be described as direct and indirect The direct effects refer to the influence of the contrast agent molecules on the perfused organ through chemotoxic and osmotic mechanisms The indirect effects refer to the influence on that organ from the temporary absence of blood in the vessels With the synthesis of less toxic contrast media, their direct effects will decrease, while their indirect effects will become relatively more important In angiography a situation may then arise in which the absence of some components of blood might have more biologic effects than the presence of contrast agent molecules If so, some components of the blood might be evaluated as vital components in some contrast agent formulations, while other components of blood might be omitted with less immediate effects Some of the ions in normal blood could be such components

The present investigation deals with the effects from a varying ion content in contrast agent solutions on the veins in the bat wing The muscle cells in these veins have a rhythmic spontaneous contractile activity just as the muscle cells in the mammalian heart, and, furthermore, there is an embryologic development of the heart from spontaneously contracting veins It was therefore thought that knowledge of the effects of different contrast agents on the contractions of the veins in the bat wing might give some guidance concerning the formulation of contrast agent solutions for later testing in coronary angiography

Material and Method

Adult nordic bats, Eptesicus nilsonii, were used Before and between the experiments the bats were stored hibernating in a refrigerator at a temperature of 6 to 8°C Before an experiment the bats were kept at room temperature for about one and a half hours

The unanesthetized bats were fixed in a special holder with one of the wings extended over a glass plate, which was placed on the stage of a microscope On the dorsal side of the wing the epithelium was peeled off on a circular area with a diameter of about 4 mm In this de-epithelialized area a major vein and two or three of its tributaries, all of which had spontaneous contractile activity, were observed at a magnification of about 400 times before and after topical application of the different test solutions to the external surface of the vessels Observations on this spontaneous contractile activity, venous vasomotion, were made after an application time of the test solution of 5, 10, 30 and 60 min and a few times after 24 hours When a test solution had stopped the spontaneous contractile activity in a vein, the test solution was rinsed away with buffered saline, and venomotion as a rule appeared again within 5 min About one hour later a new experiment could be performed in the same area Some of the observations during the experiments were recorded on a 16 mm Kodachrome II, Type A film Further details of the technique have been described previously (ALMEN & WIEDEMAN, WIEDEMAN 1967) One de-epithelialized area was as a rule used for two to four tests The applications of different test solutions

Table 2

Effects of solutions without either physiologic cations or anions

Solution	Osmolality (osm/kg H_2O)	Ions (mEq/l)		Effect on venomotion (time in minutes) 5	10	30
Cations of buffered saline	0 25 osm	Na^+	115 0		–	–
		K^+	6 2	–	–	–
		Ca^{++}	1 0	–	–	–
		Mg^{++}	2 0	–	–	–
		Cl^-	124 2	–	–	–
				–	–	–
Anions of buffered saline	0 25 osm	Na^+	124 2	–	+ +	+ +
		Cl^-	122 2	+	+ +	+ +
		$H_2PO_4^-$	1 0	+	+ +	+ +
		HCO_3^-	1 0	+ +	+ +	+ +
				+ +	+ +	+ +
				+ +	+ +	+ +

For explanation of symbols, see Table 1

anion, Cl^- The other solution had the same anion content as buffered saline while it contained only one cation, Na^+ Six applications were made with each solution In all 6 experiments with the solution containing the cations of buffered saline spontaneous contractions were still observed in the veins after an application time of 30 min Already after an application time of 10 min, venomotion had stopped in all the 6 experiments in which the test solution did not contain the cations of buffered saline The individual results and the composition of the test solutions are given in Table 2

Discussion and Conclusion The results indicate that following a contact time of 30 min or less, an abnormal anion content has less deleterious effects on venomotion than an abnormal cation content The results also indicate that for the maintenance of spontaneous venous contractions there must be more cations than Na^+ in the test solution As an abnormal anion content of the test solution does not have the same immediate deleterious effect on venomotion as an abnormal cation content, it is suggested that it might be possible to exchange the anions of buffered saline for contrast agent anions without immediate deleterious effects on venomotion

Effects of varying cation composition in solutions with contrast agent acids as anions

The most commonly used contrast agent solutions for angiography have sodium ions or meglumine ions as their principal cations Four solutions of sodium metrizoate and 4 of meglumine metrizoate were prepared To these solutions different amounts

Table 1

Effects of solutions not containing physiologic cations and anions

Solution	Osmolality ($osm/kg\ H_2O$) and Iodine content (mg I/ml)	Ions (mEq/l)		Effect on venomotion				
				5	10	30	60 min	24 h
Buffered saline	0 25 osm	Na^+	115	–	–	–		–
		K^+	6 2	–	–	–	–	–
	No iodine	Ca^{++}	1 0	–	–	–	–	–
		Mg^{++}	2 0	–	–		–	
		Cl^-	122 2	–	–	–	–	
		$H_2PO_4^-$	1 0	–	–	–	–	
		HCO_3^-	1 0	–	–	–	–	
				–	–	–	–	
				–	–	–		
				–	–	–	–	
Meglumine metrizoate	0 26 osm	Meglumine⁺	131 5	+ +	+ +			
	50 mg I	metrizoate⁻	131 5	+ +	+ +			
				+ +	+ +			
				+ +	+ +			
				+ +	+ +			
				+ +	+ +			
Metrizamide	0 24 osm	No ions		+ +	+ +			
	150 mg I			+ +	+ +			
		A molecular		+ +	+ +			
		solution of		+ +	+ +			
		metrizamide		+ +	+ +			
				+ +	+ +			
Glucose	0 25 osm	No ions		+ +	+ +			
	No iodine			+ +	+ +			
		A molecular		+ +	+ +			
		solution of		+ +	+ +			
		glucose		+ +	+ +			
				+ +	+ +			

The effect of the different test solutions on venous vasomotion at varying time of application were scored as follows – *None* of the veins had stopped their spontaneous contractile activity + *Some* of the veins had stopped their spontaneous contractile activity + + *All* of the veins had stopped their spontaneous contractile activity

performed in order to find out whether some ions are more important than others concerning the preservation of spontaneous venous vasomotion

Effects of solutions without either physiologic cations or physiologic anions

Two solutions which both had an osmolality of about 0 25 osm were used One of them had the same cation content as buffered saline while it contained only one

Table 2

Effects of solutions without either physiologic cations or anions

Solution	Osmolality (osm/kg H_2O)	Ions (mEq/l)		Effect on venomotion (time in minutes)		
				5	10	30
Cations of buffered saline	0 25 osm	Na^+	115 0	–	–	–
		K^+	6 2	–	–	–
		Ca^{++}	1 0	–	–	–
		Mg^{++}	2 0		–	–
		Cl^-	124 2	–	–	–
				–	–	–
Anions of buffered saline	0 25 osm	Na^+	124 2	–	+ +	+ +
		Cl	122 2	+	+ +	+ +
		$H_2PO_4^-$	1 0	+	+ +	+ +
		HCO_3^-	1 0	+ +	+ +	+ +
				+ +	+ +	+ +
				+ +	+ +	+ +

For explanation of symbols see Table 1

anion, Cl^- The other solution had the same anion content as buffered saline while it contained only one cation, Na^+ Six applications were made with each solution In all 6 experiments with the solution containing the cations of buffered saline spontaneous contractions were still observed in the veins after an application time of 30 min Already after an application time of 10 min, venomotion had stopped in all the 6 experiments in which the test solution did not contain the cations of buffered saline The individual results and the composition of the test solutions are given in Table 2

Discussion and Conclusion The results indicate that following a contact time of 30 min or less, an abnormal anion content has less deleterious effects on venomotion than an abnormal cation content The results also indicate that for the maintenance of spontaneous venous contractions there must be more cations than Na^+ in the test solution As an abnormal anion content of the test solution does not have the same immediate deleterious effect on venomotion as an abnormal cation content, it is suggested that it might be possible to exchange the anions of buffered saline for contrast agent anions without immediate deleterious effects on venomotion

Effects of varying cation composition in solutions with contrast agent acids as anions

The most commonly used contrast agent solutions for angiography have sodium ions or meglumine ions as their principal cations Four solutions of sodium metrizoate and 4 of meglumine metrizoate were prepared To these solutions different amounts

Table 3

Effects of varying cation composition in solutions with contrast agent acids as anions

Solution	Osmolality (osm/kg H_2O) and Iodine content (mg I/ml)	Ions (mEq/l)		Effect on venomotion (time in minutes)			
				5	10	30	60
Experiments with various solutions of sodium metrizoate							
Na-metrizoate	0.26 osm	Na^+	131.5	+ +	+ +		
	50 mg I	metrizoate$^-$	131.5	+ +	+ +		
				+ +	+ +		
				+ +	+ +		
				+ +	+ +		
Na, Ca, Mg-metrizoate	0.26 osm						
	50 mg I	Na^+	127.0	+	+ +	+ +	
		Ca^{++}	2.7	+	+ +	+ +	
		Mg^{++}	2.0	+	+ +	+ +	
		metrizoate$^-$	131.5	+ +	+ +		
				+	+ +		
				+ +	+ +		
				+ +	+		
				+	+ –		
Na, K-metrizoate	0.27 osm	Na^+	131.5				+ –
	50 mg I	K^+	4.0	+	+	+	+ –
		metrizoate	131.5		+ +	–	
		Cl	4.0	+	+ +	+ +	
					+ +	+ +	
Na, K, Ca, Mg-metrizoate	0.27 osm	Na^+	127.0				
	50 mg I	K^+	4.0		–		–
		Ca^{++}	2.7				
		Mg^{++}	2.0		–	+	+ +
		metrizoate$^-$	131.7	–		+ +	+ +
		Cl^-	4.0	–		+ +	

of K^+, Ca^{++} and Mg^{++} had been added. All 8 solutions had an iodine content of 50 mg I/ml and their osmolalities were about 0.25 to 0.30 osm. Details concerning the composition of the different contrast agent solutions are given in Table 3.

While the sodium metrizoate in all experiments stopped venous vasomotion within 5 min, the Na/K/Ca/Mg-metrizoate did not stop venous vasomotion in any of the experiments within the same time of application. The effects of the Na/K-metrizoate and *Na/Ca/Mg-metrizoate* were lying between these extremes. The results of the individual experiments concerning sodium metrizoate solutions with added cations appear in Table 3, from which it appears that the Na/K/Ca/Mg-metrizoate solution had the least deleterious effects on venous vasomotion.

Table 3 (*cont*)

Solution	Osmolality (osm/kg H_2O) and Iodine content (mg I/ml)	Ions (mEq/l)	Effect on venomotion (time in minutes) 5	10	30	60
Experiments with meglumine metrizoate						
Meglumine metrizoate	0 26 osm 50 mg I	Meglumine⁺ 131 5	+ +	+ +		
		metrizoate⁻ 131 5	+ +	+ +		
			+ +	+ +		
			+ +	+ +		
			+ +	+ +		
			+ +	+ +		
Meglumine, Ca metrizoate	0 26 osm 50 mg I	Meglumine⁺ 128 2	+	+ +		
		Ca^{++} 3 1	+ +	– +		
		metrizoate⁻ 131 3	+ +	– –		
			+ +	– –		
			+ +	+ +		
Meglumine K, Ca metrizoate	0 27 osm 50 mg I	Meglumine⁺ 128 2	+ +	+ –		
		K^+ 4 0	+ +	+ +		
		Ca^{++} 3 1	+ +	–		
		metrizoate⁻ 131 3	+ +	+ +		
		Cl^- 4 0				
Meglumine K, Ca Mg metrizoate	0 28 osm 50 mg I	Meglumine⁺ 128 2	+ +	– +		
		K^+ 4 0	+ +	+ +		
		Ca^{++} 3 1	+ +	+ +		
		Mg^{++} 4 0	+ +	+ +		
		metrizoate⁻ 131 3				
		Cl^- 8 0				

For explanation of symbols see Table 1

In all experiments the meglumine metrizoate solution stopped venous vasomotion within 5 min *The addition of* K, Ca or Mg *ions to meglumine metrizoate did not change this effect*

Discussion and Conclusion The Na/K/Ca/Mg metrizoate solution, which was the only test solution *containing all the* four cations of buffered saline, had the least deleterious effects on venous vasomotion of the *different ionic* contrast agents tested It is also of interest that the addition of K/Ca/Mg ions to a meglumine metrizoate solution did not, with the concentrations used, change its unfavorable effects on venous vasomotion

The goal, when deciding upon the composition of a contrast medium, is the combination of a high iodine content and a low biologic effect, i e without a deleterious effect on venous vasomotion *Venous* vasomotion can be stopped by a high osmola-

Table 4

Effects of solutions containing non ionic, or ionic contrast agents or these agents combined

Solution	Osmolality (osm/kg H_2O) and Iodine content (mg I/ml)	Ions (mEq/l)		Effects on venomotion (time in minutes) 5	10
A Metrizamide	0 24 osm	No ions		+ +	+ -
	150 mg I	A molecular		+ +	+ -
		solution of		+ +	+ +
		metrizamide		+ +	+ +
				+ +	+ +
				+ +	+ +
B Metrizoate solution	0 8 osm	Na^+	381	+ +	+ +
	150 mg I	K^+	12 0	+ +	+ +
		Ca^{++}	8 2	+ +	+ +
		Mg^{++}	5 9	+ +	+ +
		metrizoate	395	+ +	+ +
		Cl	12 0	+ +	+ +
C Metrizamide and Metrizoate solution	0 42 osm	Na^+	127	–	–
	150 mg I	K^+	4 0	–	–
		Ca^{++}	2 7		
		Mg^{++}	2 0	–	
		metrizoate	131 7		+
		Cl	4 0	+	+ +
		and a molecular solution of metrizamide			

For explanation of symbols see Table 1

lity or absence of physiologic cations in the contrast agent solution (ALMÉN & WIEDEMAN, ALMEN) At present the non ionic contrast agent solutions have the lowest osmolality in relation to their iodine concentration in water solutions Therefore, such compounds should be used in contrast media with intended low effects on venous vasomotion However, the presence of physiologic cations is necessary for normal venous vasomotion and is therefore also required The anions which have to accompany these physiologic cations may be iodinated contrast agent anions as has been shown in the present experiments This will further increase the iodine concentration Therefore, the best combination of high iodine content, low osmolality and presence of physiologic cations would at present be a solution containing a non ionic contrast agent, e g , metrizamide, and physiologic cations as salt of a contrast agent acid, e g , Na/K/Ca/Mg metrizoate

Effects of solutions containing non ionic, or ionic contrast agents or these agents combined

All three contrast agent solutions had in iodine concentration of 150 mg I/ml The data on osmolality and ion content of the three solutions varied and are given in Table 4

Both the metrizamide solution (solution A) and the Na/K/Ca/Mg metrizoate solution (solution B) stopped venous vasomotion in all observed vessels in all experiments within 5 min

The contrast agent solution which contained both metrizamide and Na/K/Ca/Mg-metrizoate (solution C) had less effects Within the same time of application (5 min) it did not stop vasomotion in any of the veins in 5 of 6 experiments and in the remaining experiment it stopped contractile activity in one of the observed veins Also after an application time of 10 min solution C had less effects on venous vasomotion than solutions A or B

The results of the individual experiments are given in Table 4

Discussion It is in agreement with previous sections to assume that the metrizamide solution (A) stopped venous vasomotion due to lack of physiologic cations It is also in agreement with previous results (ALMÉN & WIEDEMAN) to assume that the Na/K/Ca/Mg metrizoate solution (B) stopped venous vasomotion on account of its high osmolality

Solution C, which contained 50 mg I/ml as Na/K/Ca/Mg metrizoate and 100 mg I/ml as metrizamide, was composed of two volume parts of solution A and one volume part of solution B Solution C then contained the physiologic cations which were absent in solution A It also has a lower osmolality than solution B

Conclusion Contrast media which are composed of non ionic and ionic contrast agents deserve further investigation concerning their potential use in angiography because they combine low osmolality and presence of cations (Na, K, Ca and Mg) which are necessary for normal spontaneous contractile activity of muscle cells

SUMMARY

The effects on spontaneous venous vasomotion from topical application of different contrast media were investigated in the bat wing Spontaneous venous vasomotion could be stopped either by a high osmolality of the contrast medium or by absence of cations (Na^+, K^+ Ca^{++} Mg^{++}) in the solution The highest contrast medium concentration (mg I/ml) which did not stop venous vasomotion, was obtained when a non ionic contrast medium solution with low osmolality was mixed with a solution containing Na, K, Ca, Mg-salts of an ionic medium

ZUSAMMENFASSUNG

[illegible] der Fledermaus wurde untersucht. Die [illegible] oder durch [illegible] (Na, K, Ca, Mg) [illegible] der L[illegible] werden. Die [illegible] (mg I/ml) [illegible] mit niedriger Osmolalität [illegible] Na, K, Ca und Mg enthielt, gemischt wurde.

RÉSUMÉ

Les effets de l'application locale de différents moyens de contraste sur la motricité vasculaire [illegible] ont été étudiés sur l'aile de la chauve-souris. La motricité vasculaire [illegible] spontanée peut être arrêtée soit par une forte osmolalité du moyen de contraste soit en l'absence de cations (Na, K, Ca, Mg) dans la solution. La plus forte concentration de moyen de contraste (mg I/ml) qui n'arrête pas la motricité vasculaire [illegible] a été obtenue quand on mélange une solution à faible osmolalité de moyen de contraste non ionique avec une solution contenant des sels de Na, K, Ca, Mg d'un moyen de contraste ionique.

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CONTRAST MEDIA WITH AND WITHOUT CALCIUM FOR CARDIOANGIOGRAPHY IN CHILDREN

D J TAY, A R LEVIN, E SCHUBERT and H A BALTAXE

From among the numerous commercially available preparations for contrast examinations, the angiographer has to make a rational decision for selecting one medium in preference to another Several animal experiments have demonstrated that the addition of calcium ions, with or without magnesium ions, to contrast media led to reduction of both general acute toxicity and toxicity to specific organs such as the heart and the brain (BROWN et coll 1967, JACOBSSON & PAULIN 1967, JUDKINS, SALVESEN et coll 1967 a, b) This has not been confirmed in human trials

The present investigation was designed to analyse a series of clinical and biochemical parameters following injections of a commonly employed contrast medium without calcium, and another with added calcium ions The two media selected for the double-blind randomized investigation were meglumine diatrizoate (66 %) and sodium diatrizoate (10 %) (Renografin-76, E R Squibb & Sons, Inc), commonly used in the United States, and meglumine metrizoate (66 %), sodium metrizoate (10 %) with calcium (1 1 %) (Isopaque 370, courtesy of Sterling-Winthrop Research Institute), available commercially in Europe but not yet in the United States The preparations had the same iodine content (370 mg per ml), similar total salt concen-

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	RENOGRAFIN 76	ISOPAQUE 370
Meglumine salt	Diatrizoic acid COO, I, I, $H_3C-C(=O)-HN$, NH $C(=O)-CH_3$, I 157 mg/ml	Metrizoic acid COO, I, I, $H_3C-C(=O)-N(CH_3)$, NH $C(=O)$ CH, I 157 mg/ml
Sodium	4 43 mg/ml	3 57 mg ml
Iodine	370 mg/ml	370 mg/ml
Calcium	none	0 34 mg/ml

Fig 1 Comparison of Isopaque 370 and Renografin-76 The similarity between the two compounds is apparent except for the addition of calcium in Isopaque

tration, and almost equally low sodium content (190 mEq/l in Renografin-76, 4 48 mg per ml) and 160 mEq/l in Isopaque-370 (3 57 mg per ml) (Fig 1) The osmolality for each was approximately 2 000 mOsm/kg water Toxicologic, pharmacologic and clinical investigations in Norway and other European countries, indicated that the anion moieties metrizoate and diatrizoate per se, appeared to be equal with respect to clinical tolerance, acute general toxicity and specific organ toxicity (Dahlström 1967, Hurst et coll 1967) Thus the only significant variable between the two selected media was the presence of calcium in Isopaque-370 in a concentration of 34 mg/100 ml, that is, 6 to 7 times the concentration of ionized calcium in serum

Material and Methods

Ninety-three angiographies were performed in 50 children aged 15 months to 17 years with a variety of congenital cardiac malformations, who were undergoing routine diagnostic cardiac catheterization performed under local anesthesia following sedation with meperidine, chlorpromazine and promethazine (Smith et coll 1958) In a double blind and randomized fashion, either Renografin-76 (10 % weight/volume sodium diatrizoate and 66 % weight/volume meglumine diatrizoate, subsequently referred to as Renografin) or Isopaque-370 (10 % weight/volume sodium metrizoate, 66 % weight/volume meglumine metrizoate and 1 1 % weight/volume calcium metrizoate, subsequently referred to as Isopaque) was used One ml/kg body-weight was injected with a Viamonte-Hobbs model 2 000 power injector through either N I H or Gensini catheters at a rate of 16 to 20 ml/s

The age distribution for each group of patients was not significantly different The mean age for patients receiving Isopaque was 8 04 years compared to 9 86 years for those receiving Renografin Each group had one patient under two years of age In the Isopaque group, 19 were between 2 and 10 years, 7 over the age of 10 years In the Renografin group, respective numbers were 10 children between 2 and 10 years, 12 patients were above 10 years of age

Electrocardiograms, left ventricular systolic (LVSP) and end-diastolic (LVEDP) pressures and the rate of the left ventricular pressure rise (dP/dt) were recorded with

a D R 12 Electronics for Medicine recorder just before injection of contrast material and at 1, 5, and 15 minutes thereafter Two electrocardiographic leads were recorded, namely standard lead II and III An Electronics for Medicine Model RC-1 differentiating circuit was utilized for measurement and simultaneous recording of the dP-dt Control blood samples for serum osmolality, sodium, chloride, potassium, calcium, and urea nitrogen, as well as samples for arterial and venous pH, blood gases (P_O, and P_{CO_2}) and complete blood count including platelet count were obtained just before the injection and before any contrast medium had been administered Samples were repeated at 1, 5 and 15 minutes following injection Final samples were drawn 4 hours following the last cardioangiography Blood gases were measured with an Instrumentation Laboratory 113 pH blood gas analyzer Serum osmolality was obtained by the method of freezing point depression utilizing an Advance Instruments osmometer Serum sodium and potassium were measured by an Instru mentation Laboratories flame photometer Chlorides were determined with a Cotlove chloridometer by the amperometric technique The Berthelot reaction was used to determine the blood urea nitrogen Blood counts were performed by standard laboratory technique All determinations were accomplished with 5 ml of blood (LEVIN et coll 1969)

In the group of 50 patients 27 children received Isopaque Of these, 7 patients had left to-right shunts, 1 a right to-left shunt and 2 bidirectional ventricular shunts There were, in addition, 5 patients with pure left heart lesions, 6 with pure right heart lesions and 6 patients who were catheterized for evaluation of corrective surgical procedures undertaken one year previously None of the patients were known to have underlying cardiomyopathy Twenty three children received Renografin and of these 7 had left to right shunts, 1 a right to-left shunt, and 2 bidirectional shunts Six of these patients had pure left heart lesions, one a pure right heart lesion, and 3 patients underwent catheterization for evaluation of operative procedures under taken one year previously In addition, there were 3 patients who were catheterized for suggested heart disease and who were found to have normal hearts

In 43 children, two cardioangiographies at least 25 minutes apart, followed by sequential determinations as described, were performed In the Isopaque group, 23 of the 27 patients had a second cardioangiography, for a total of 50 examinations with this medium In the 23 patients receiving Renografin, 20 were subjected to a second cardioangiography, for a total of 43 examinations performed with this substance

Results

Review of the data revealed no significant differences occurring with respect to site of injection or the type of lesion present Similarly, in those patients having two cardioangiographies, no significant differences were noted between those with initial injections on the left side of the heart compared to those whose initial injections were performed on the right side of the heart In the 23 patients having two cardioangio-

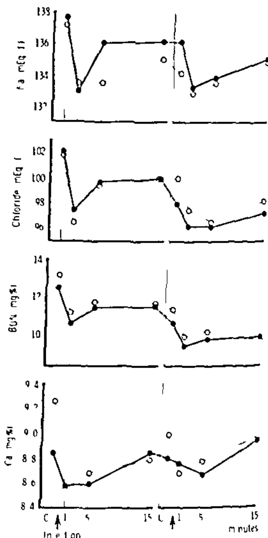


Fig 2 Serum electrolytes Mean values of changes at 1, 5, and 15 min following injections of contrast media Broken lines indicate variable time between first and second cardioangiographies Arrows indicate time of injection A sharp sig-

angiography C_2 control value just before second cardioangiography Na sodium BUN = urea nitrogen Ca = calcium ●—● Isopaque, ○—○ Renografin

graphies with Isopaque, the first cardioangiography was left-sided in 14 and right-sided in 9 Using Renografin, 12 of 20 patients having two cardioangiographies had the initial one in the left heart while the first one was in the right heart in the remaining eight children

As expected for agents of equi-iodine content and similar physical properties there were no differences in quality of the contrast demonstration between the two compounds No serious adverse reactions to contrast material occurred during the course of the present study

Blood chemistry Fig 2 records the mean blood chemistry changes A mild but consistent drop occurred in serum sodium, chloride, calcium and urea nitrogen for both Isopaque and Renografin At one minute following the first cardioangiography, these changes were statistically significant ($p < 0.05$) the mean drop in sodium was 4 6 mEq/l for Isopaque and 3 6 mEq/l for Renografin, in chloride 4 6 mEq/l for Isopaque and 5 3 mEq/l for Renografin, in urea nitrogen 1 9 mg% for Isopaque

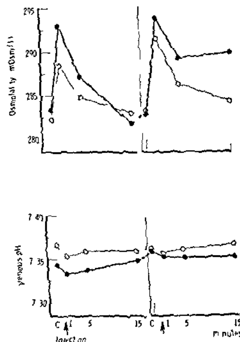


Fig 3

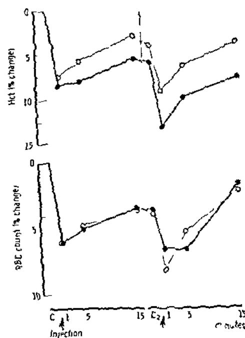


Fig 4

Fig 3 Mean values of osmolality and pH following cardioangiography Consistent but insignificant rise in osmolality *most marked at one min following injection* The fall in pH for each contrast material was not significant Symbols as in Fig 2

Fig 4 Mean values of fall in hematocrit and red blood cell count expressed as percentage change The lowest values *occurred at one minute following* injection of contrast media The values at 5 min indicated beginning recovery Symbols as in Fig 2

and 2 1 mg % for Renografin, and in calcium 0 3 mg % for Isopaque and 0 7 *mg % for Renografin*

A mild but consistent rise in serum osmolality occurred (Fig 3) being maximum at one minute after injection However, at one minute following the first cardioangiography, the mean values were still well within the physiologically normal range a mean rise of 9 6 mOsm/l for Isopaque and 6 3 mOsm/l for Renografin Of the 410 osmolality determinations performed, only two values above 320 mOsm/l were observed one, a change from control value of 302 mOsm/l to 327 mOsm/l, the other, from control of 306 mOsm/l to 332 mOsm/l Both represented an increase of 8 per cent a rise of unusual magnitude in the present material Recovery of blood chemistry changes began within 5 min and at 15 min most parameters had returned to near control values Small changes in serum potassium, arterial P_{O_2} and P_{CO_2} were inconsistent and not statistically significant A consistent but minimal drop in pH occurred (Fig 3) The observed changes were not significantly different for Isopaque and Renografin, except for the drop in calcium which though physiologically insignificant, was sharper for Renografin than for Isopaque

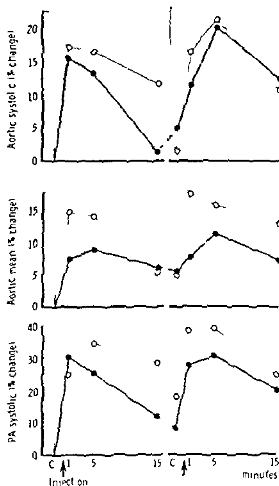


Fig 5

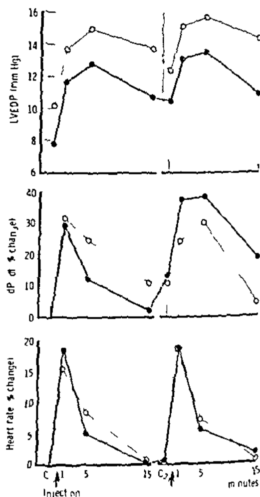


Fig 6

Fig 5 The effects of cardioangiography on aortic and pulmonary arterial pressures expressed as percentage change The elevations in pressures were significant (p 0 02) consistent and sustained throughout the first 5 min following cardioangiography for each parameter The slight differences between Isopaque and Renografin were not significant Symbols as in Fig 2

Fig 6 Mean
and heart rate
and for that
mmHg Symbols as in Fig 2

Blood counts For both Isopaque and Renografin, the red blood cell count dropped an average of 6 per cent and the hematocrit 7 5 per cent (per cent change from control value) at one minute following the first cardioangiography (Fig 4) The 5 min blood counts showed beginning recovery towards control values The changes in white blood cell count and platelet count were minimal and inconsistent However, 4 hours after completion of cardiac catheterization, a mild leucocytosis was uniformly present with a mean white blood cell count of 13 200/mm³ for Isopaque and 11 000/mm³ for Renografin (both approximately twice the control count)

Hemodynamic data Fig 5 presents the mean values of pressures as expressed in percentage rise over control values There was a sustained rise in systolic pressures throughout the first 5 min following cardioangiography At one minute following the first cardioangiography, these elevations were statistically significant ($p < 0\ 02$) the aortic systolic pressure rose 15 4 per cent for Isopaque and 17 3 per cent for Renografin, mean aortic pressure 7 2 per cent for Isopaque and 14 7 per cent for Renografin, and pulmonary arterial systolic pressure 30 6 per cent for Isopaque and 24 7 per cent for Renografin

The left ventricular end diastolic pressure (LVEDP) rose significantly ($p < 0\ 005$), usually to values above 12 mmHg (Fig 6) When right sided and left-sided injections were compared, no difference in the magnitude to rise of LVEDP was noted The pressure changes did not differ significantly between Isopaque and Renografin Specifically, the rise in LVEDP was identical for both agents

As a measure of myocardial contractility, left ventricular dP/dt (first derivative) was recorded A rapid mean rise of 29 per cent for Isopaque and 31 per cent for Renografin occurred at one minute after the first cardioangiography (Fig 6)

ECG Maximal rise in heart rate occurred within one minute Following the first cardioangiography, the one minute rise was 17 per cent for Isopaque and 15 per cent for Renografin (Fig 6) The gradual rise in heart rate commenced immediately after injection, as was observed from the continuously recorded electrocardiogram during and after injection into the left ventricle or aortic root Bradycardia following angiocardiography did not occur There was no difference between Isopaque and Renografin with regard to the frequency of isolated ectopic beats occurring during injection, usually related to catheter 'fling' No transient or prolonged ST-segment or T wave changes occurred with either of the two agents used

Discussion

The major physical and chemical characteristics of current contrast media consist of the *anion moiety* (tri iodinated organic acid), cation moiety, concentration (weight/volume) osmolality, viscosity, and pH Some well established practical generalizations may be made about the three most commonly employed salts of tri iodinated organic acids, *namely diatrizoate*, iothalamate and metrizoate When employed at the usual dosage and concentrations (50–90%) for cardioangiography, the toxicity of a pure sodium salt, both general and to specific organs such as the brain and the cardiovascular system, is higher than a combination of a sodium salt with a methyl glucamine (meglumine) salt (BROWN et coll 1967, FISCHER et coll 1962, GENSINI et coll 1964, GOOTMAN et coll 1970, JACOBSSON & PAULIN, SALVESEN a, b) The presence of the *meglumine salt*, however, generally adds to the viscosity of the preparation Higher viscosity increases the technical difficulty of rapid delivery of a contrast medium The high osmolality of contrast agents varies between 5 and 10 times that of serum and is roughly proportional to the percentage of iodine The

allowable range of pH is between 6 5 and 7 5, however, the more desirable preparations maintain a pH between 7 20 and 7 40

Virtually all contrast media in common clinical use contain sodium (as a cation of tri-iodinated organic salts) in hypertonic concentrations up to 1 250 mEq/l Extensive experiments in animals (GENSINI et coll, GOOTMAN et coll) have demonstrated a direct relationship between myocardial toxicity and the concentration of sodium salts The idea that the addition of calcium ions may counteract and diminish the side-effects of rapid injections of hypertonic sodium solutions is based on theoretical considerations related to competition between sodium and calcium for sites on the cell membrane (GROLLMAN & GROSSMAN 1970, MOLLER 1961, SALVESEN et coll a, WELT & BLYTHE 1970) When rapid changes in the external medium of a cell are made, calcium is thought to have the function of stabilizing the cell membrane (BARR 1969) It was also found that the lowest acute toxicity in rabbits was reached at a specific ratio of calcium to sodium ions present in the contrast medium, namely 6 to 7 times the ratio in human plasma The amount of calcium contained in the Isopaque preparation used, 0 34 mg/ml, is based on these experimental findings

Blood chemistry Elevations of serum osmolality observed were consistent, but only minimal (Fig 3) Previous examinations of serum osmolality from this laboratory (GILLADOGA 1969, LEVIN et coll) and by other workers (GIAMMONA et coll 1963, SOTOS et coll 1960), utilizing a variety of contrast media, have shown a wide range of increase GIAMMONA et coll encountered 2 children with serum osmolality of 360 mOsm/l, using Renovist which contained 755 mEq/l sodium as analysed in their laboratory The media used in the present material, Isopaque and Renografin, contained only 160 and 190 mEq/l sodium, respectively These observations would invite speculation that for agents with equal osmolality, the ones with higher sodium content tend to cause greater rise in serum osmolality However, animal experiments (SOTOS et coll, 1960, 1962), demonstrated equal rises in plasma osmolality for equal osmolar quantities of sodium chloride, sucrose, mannitol or urea

The consistent drop of serum sodium, chloride, calcium and urea nitrogen (Fig 2), although still within the normal range, is the result of the well recognized phenomenon of hemodilution immediately following injection of contrast agents (FRIESINGER et coll 1965, GILLADOGA, ISERI et coll 1965, KLOSTER et coll 1966, LEVIN et coll) Of interest is the observation that at 5 min these values were closer to the control value, suggesting that within 5 min, recovery from maximum hemodilution had already commenced

As expected, a drop of pH occurred (Fig 3) The observed changes in pH were small and physiologically insignificant for both Isopaque and Renografin The tendency to acidosis is the result of acidity of most contrast media (MARSHALL & HENDERSON 1968) and of hypertonicity per se (MARSHALL & HENDERSON, SOTOS et coll 1962) Thus contrast media to be preferred are those buffered to maintain a stable pH above 7 20

Blood count HURST et coll and McINTOSH et coll (1967) observed fleeting acute

red blood cell shrinkage occurring within seconds after injection of contrast medium Similar changes have been noted by SCHIANTARELLI et coll (1973), who observed deformation of red blood cells which could be reversed by washing with physiologic saline solution Such changes were not investigated in the present material, but by one minute, at which time the first post-injection samples for complete blood count were drawn, the observed mean hematocrit drop of 7 5 per cent probably reflected hemodilution (Fig 4) This is substantiated by the concomitant 6 per cent drop in absolute red blood cell count

Review of the literature indicates that the maximum change in hematocrit in the present material (Fig 4) is less in extent than previously reported FRIESINGER et coll observed a 10 to 20 per cent drop within one minute LEVIN et coll noted a 14 to 18 per cent drop at 5 min with a similar change for hemoglobin, while other investigators have observed changes of 16 to 20 per cent during the first 5 min (BROWN et coll 1965, ROSENTHAL et coll 1973) The common denominator of the preparations used in these reports was their higher sodium content, compared to the lower sodium content of the compounds used in the present investigation Based on experimental and clinical examinations, the desirability of contrast media containing little or no sodium salt has been expressed by many investigators (FISHER et coll, GENSINI et coll, GOOTMAN et coll) Whether high sodium content is also a major determinant of more profound hemodilution awaits further investigation

A striking rise in white blood cell count was present 4 hours after completion of cardiac catheterization This is likely a nonspecific reaction to stress in general Another nonspecific manifestation of stress following cardiac catheterization with cardioangiography is low-grade fever, observed by GILLADOGA et coll (1972) in 39 per cent of patients

Hemodynamics Peripheral vasodilation follows injection of contrast media for cardioangiography (BROWN et coll 1965, FRIESINGER et coll) A fall in blood pressure is often observed in adults (BROWN et coll 1965, JACOBSSON & PAULIN, GOOTMAN et coll, KAVANAGH GRAY 1973, KLOSTER et coll), especially following selective injection into coronary arteries The maximum fall in systolic arterial pressure, generally reported as averaging 20 to 30 per cent (BROWN et coll 1965, FRIESINGER et coll KLOSTER et coll) characteristically occurs between 20 and 40 s after injection of contrast medium, with recovery by one minute In children, when no general anesthesia is employed and excluding the gravely ill and hypoxic newborn generally little or no fall in blood pressure occurs In the present material, it was observed that for both Isopaque and Renografin, the aortic systolic and mean pressures at one min were higher than the control level in 80 per cent of children The pressures gradually decline to near control values at 15 min (Fig 5) Similar increases occurred in left ventricular and pulmonary arterial peak systolic pressures

Elevation of left ventricular and diastolic pressure above normal values commonly occurs following cardioangiography This observation is more profound after coronary angiography, and is thought to be due to the direct effect of contrast media on

the myocardium (KAVANAGH-GRAY 1972, 1973) JUDKINS has stated that for equal amounts of iodine injected, LVEDP rises least when using agents containing calcium compared to those without calcium In the present material where injections were intracavitary, however, this observation was not confirmed and the rise in LVEDP was the same for the calcium-containing contrast medium as for the one without calcium

Generally, the rate of left ventricular pressure rise (dP/dt) increased (Fig 6) This has also been demonstrated by KAVANAGH-GRAY (1972) and suggests that in children with congenital heart disease, where myocardial function is usually intrinsically adequate, conventional doses of contrast media do not significantly impair myocardial contractility

Conclusions For two contrast media with equal iodine and sodium content and osmolality, no clinical nor hemodynamic differences in response could be detected between the one containing calcium (Isopaque-370) and the other without calcium ions (Renografin-76) If the speculation that calcium acts beneficially by being antagonist to sodium is correct, then the absence of ameliorating effects of calcium could perhaps be ascribed to the fact that the two agents used were of relatively low sodium content (that is, one-fourth to one-half the sodium concentration in other commonly employed contrast agents) A beneficial effect of the addition of calcium ions to contrast agents, if any, should probably be sought for in adults undergoing selective coronary angiography where the myocardial side-effects, related to concentrated amounts of contrast medium in the coronary system, are often profound

SUMMARY

The possible beneficial effects of added calcium ions to contrast media to diminish myocardial toxicity was evaluated in 93 cardiac catheterizations with cardioangiography, performed in 50 children and adolescents Two contrast media with equal iodine content (370 mg/ml) and similar physical properties were used Isopaque-370 containing 0 34 mg calcium/ml, and Renografin 76, not containing calcium It is concluded that addition of calcium to contrast media for cardioangiography in children and adolescents does not alter their myocardial, fluid or electrolyte effects when injected selectively into the cardiac chambers or great vessels

ZUSAMMENFASSUNG

Die eventuellen gunstigen Effekte von zusatzlichen Calcium-Ionen zu Kontrastmitteln, um die Toxizitat auf das Myokard zu vermindern wurde bei 93 Herzkatheterisierungen mit Kardioangiographie, die bei 50 Kindern und Jugendlichen vorgenommen worden waren, festgestellt Zwei Kontrastmittel mit gleichem Jodgehalt (370 mg/ml) und ahnlichen physikalischen Eigenschaften wurden verwendet Isopaque 370 das 0,34 mg Calcium/ml enthielt, und Renografin-76, das kein Calcium enthielt Es wird aus den Untersuchungen geschlossen, dass der Zusatz von Calcium zu Kontrastmitteln fur die Kardioangiographie bei Kindern und Jugendlichen nicht deren Einfluss auf das Myokard, die Flussigkeits

oder Elektrolytverhaltnisse ändert, wenn diese selektiv in die Herzkammern oder grossen Gefasse injiziert werden

RESUMÉ

Les effets benefiques possibles de l addition d ions de calcium aux moyens de contraste pour diminuer leur toxicite myocardique a eté étudié au cours de 93 cathétérismes cardiaques avec cardioangiographie effectues chez 50 enfants et adolescents Les auteurs ont utilise deux moyens de contraste ayant un contenu en iode égal (370 mg/ml) et des proprietes physiques semblables Isopaque 370 contenant 0,34 mg de calcium/ml et Renografin76 ne contenant

dans les cavites cardiaques ou les grands vaisseaux

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INFLUENCE OF THE CATION ON THE SIDE-EFFECTS OF UROGRAPHIC CONTRAST MEDIA

S G DAHL, O LINAKER, Å MELLBYE and KARI SVEEN

The triiodinated intravascular contrast media used today are generally well tolerated Although serious adverse reactions may occur, the majority of side-effects are transient and of minor or moderate severity Still they may be annoying to the patient as well as to the physician, and it is desirable to take all possible precautions to reduce their incidence In addition to the radiologic technique employed and the kind and amount of contrast medium used, several other factors may influence the incidence of side effects These are for instance concomitant administration of drugs and the age and sex of the patient

The incidence of allergic reactions in urography seems to be reduced by premedication with antihistamines (OLSSON 1951, 1962) In patients who previously have reacted to contrast media or have had any severe allergic reaction, intravenous administration of steroids before the examination has been advocated by SAXTON (1969)

Premedication with atropine has been demonstrated to reduce the incidence of severe reactions in urography, but to enhance the incidence of mild reactions (SVENDSEN & WILSON 1971) BEALES et coll (1969) found that a history of a previous uro

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compared, and each contrast medium could be compared to another with the same anionic or cationic part In addition, possible relations between side-effects and premedication, sex and other parameters were analysed

Material and Methods

The investigation was carried out in two subsequent steps, including all patients attending the hospital for urography from February 1971 to April 1972 (part one, series I) and from May to December 1973 (part two, series II) The total material consisted of 1 200 patients, 338 in patients and 862 out-patients

Out patients were told to take a peroral purgative, while in patients were given a 2 litre enema before the examination In patients were given 1 mg atropine orally 90 min before the examination to prevent side effects from the enema All patients were questioned about previous allergic reactions, and in case of a history of asthma, urticaria or allergic rhinitis, 100 mg diphenhydramine chloride were given orally 20 min before the examination

In the first part (series I), 4 contrast media were used in 800 urographies

MI Meglumine metrizoate 280 mg I/ml, made for experimental purposes, not commercially available

MII Meglumine-calcium (52 1) metrizoate 280 mg I/ml, available as Isopaque Cerebral 280 mg I/ml

MIII Sodium-calcium-magnesium (26 4 1 4 1) metrizoate 280 mg I/ml, available in other concentrat [illegible]

D [illegible]

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mg [illegible] some countries also as Hypaque meglumine 60 %)

In the second part (series II), two different batches (B and C) of sodium-calcium-magnesium metrizoate (MIII) were used in 400 urographies The concentration was 350 mg I/ml, as in commercially available Isopaque 350 mg I/ml

In both series, the contrast medium to be injected at each examination was determined by a previously arranged randomisation, and double blind technique was used All patients were given a dose equivalent to 7 g of iodine (25 ml of 280 mg I/ml in series I and 20 ml of 350 mg I/ml in series II)

The contrast medium was injected into a cubital vein, during 45 seconds Ureteral compression was applied after 4 min and released about 15 min later Side-effects occurring during the examination, or within 10 min after the end of the examination, were recorded on a form filled in for each patient

The same two radiologists were seeing all the patients and made the recordings of side-effects throughout both series Any obvious reactions or spontaneous comments from the patient were noted Besides, all patients were questioned in a general and standardized way whether they had experienced any sensation during the examination

graphy was not associated with a greater frequency of reactions or skin rashes This was later corroborated by WITTEN et coll (1973), neither of them found any evidence of increased sensitivity to contrast media by repeated use SHEHADI & MISHKIN (1974) found a higher incidence of side-effects in patients who previously had had reactions after a contrast medium injection Premedication with antihistamines, steroids, calcium or other drugs had no observable effects, but premedication was probably mainly used when the risk of side-effects was thought to be increased

Some reports have indicated that the age and sex of the patient may influence the likelihood of contrast media to give side-effects In 100 lumbar myelographies, clonic spasms in leg muscles occurred more frequently in men than in women, while head ache and vomiting were more frequent in women (SKALPE 1971) No significant difference in the frequency of side-effects between males and females was, however, seen in a material comprising 2 234 urographies (MACHT et coll 1966), but the age of the patient seemed to be of importance Patients aged 20 to 49 years had the highest incidence of side-effects, while patients older than 69 years had the lowest incidence SHEHADI & MISHKIN found the highest incidence of side-effects in patients aged 21 to 35 years, but no sex difference was found When giving high doses of contrast medium in connection with parathyroid venous sampling, SMITH et coll (1974), on the other hand, found that a reaction comprising rigor, pyrexia, hypotension and vomiting only occurred in patients over 50 years old

The contrast media used for urography are salts consisting of different iodine containing anions (diatrizoate, iodamide, iothalamate, metrizoate) and various cations (meglumine, sodium, calcium, magnesium) Both the anionic and the cationic part of the contrast medium may contribute to the side-effects caused by the medium In several reports the incidence of side-effects produced by different contrast media has been compared, and small differences have often been found (MACHT et coll, BEALES et coll, PEARSON et coll 1971, FREDE LARSEN et coll 1972, GRAEBNER & BAYINDIR 1970, RITCHIE & BURRAGE 1969) In many of these reports, however, different concentrations of contrast media have been used Besides, both the anionic and the cationic part of the molecule have often been different, and consequently it is difficult to determine which part of the active ingredient the observed differences may be due to

Many patients experience a sensation of warmth in connection with the injection of contrast medium in intravenous urography EDGREN & KÖHLER (1972) mention that 20 to 30 per cent of their patients had taste- and warmth-sensations A sensation of warmth is not considered a real side-effect and many reports do not include it However, as calcium is known to give a sensation of warmth in some instances (MOLLER 1965), and as some of the contrast media used in the present material contain calcium, special attention was paid to the occurrence of a sensation of warmth

The aim of the present investigation was to analyse the incidence of sensation of warmth and side-effects in intravenous urography in relation to the ionic composition of the contrast medium One diatrizoate and three metrizoate compounds were

Table 2

Number (No) of patients receiving each contrast medium, and number (No) and per cent of patients who had side-effects Contrast media MI Meglumine metrizoate, MII Meglumine-calcium metrizoate, MIII Sodium-calcium-magnesium metrizoate, DI Meglumine diatrizoate

Group	Series I										Series II					
	All contrast media		MI		MII		MIII (Batch A)		DI		Both contrast media		MIII (Batch B)		MIII (Batch C)	
	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent
Total number of patients	800		197		197		199		207		400		207		193	
Sensation of warmth	160	20 0	27	13 7	41	20 8	65	32 7	27	13 0	153	38 2	79	38 2	74	38 3
Patients with side-effects except a sensation of warmth	85	10 6	22	11 2	24	12 2	25	12 6	14	6 8	41	10 3	19	9 2	22	11 4
Nausea	54	6 8	14	7 1	18	9 1	14	7 0	8	3 9	27	6 8	12	5 8	15	7 8
Urticaria and other reactions	39	4 9	8	4 1	10	5 1	16	8 0	6	2 9	17	4 3	8	3 9	9	4 7

Table 2 reveals the frequency of side-effects for each contrast medium 'Other reactions' include sneezing, and minor, subjective side-effects like unpleasant taste, transitory headache or dizziness

The overall incidence of side-effects, except a sensation of warmth, did not differ significantly between the 4 contrast media tested in series I However, in this series, the incidence of a sensation of warmth was significantly higher for sodium-calcium-magnesium metrizoate (MIII) than for the meglumine salts of metrizoate (MI) and diatrizoate (DI) ($p<0\ 01$), and for meglumine-calcium metrizoate (MII) ($p<0\ 05$) Meglumine diatrizoate (DI) and meglumine metrizoate (MI) gave practically identical incidences of sensation of warmth Neither was there any significant difference in the incidence of sensation of warmth between meglumine metrizoate (MI) and meglumine-calcium metrizoate (MII)

The incidence of nausea was lower with meglumine diatrizoate than with the three metrizoate formulations, but the difference was not statistically significant

In series II, no significant differences between batch B and C of Isopaque 350 were revealed The overall incidence of side effects was about the same as for batch A in series I

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Table 1

Age (in years) and sex distribution of patients receiving each contrast medium Contrast media MI Meglumine metrizoate, MII Meglumine-calcium metrizoate, MIII Sodium-calcium magnesium metrizoate, DI Meglumine diatrizoate

Group	Series I										Series II					
	All contrast media		MI		MII		MIII (Batch A)		DI		Both contrast media		MIII (Batch B)		MIII (Batch C)	
	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent	No	Per cent
Females	350	43 8	89	45 2	82	41 6	87	43 7	92	44 4	164	41 0	84	40 6	80	41 5
0–30	79	9 9	20	10 2	18	9 1	20	10 1	21	10 1	34	8 5	18	8 7	16	8 3
31–60	137	17 1	38	19 3	28	14 2	35	17 6	36	17 4	70	17 5	38	18 4	32	16 6
61 <	134	16 7	31	15 7	36	18 3	32	16 1	35	16 9	60	15 0	28	13 5	32	16 6
Males	450	56 3	108	54 8	115	58 4	112	56 3	115	55 6	236	59 0	123	59 4	113	58 5
0–30	59	7 4	11	5 6	16	8 1	15	7 5	17	8 2	34	8 5	19	9 2	15	7 8
31–60	210	26 2	51	25 9	58	29 4	57	28 6	44	21 3	81	20 2	47	22 7	34	17 6
61 <	181	22 6	46	23 4	41	20 8	40	20 1	54	26 1	121	30 2	57	27 5	64	33 2
Total	800	100 0	197	100 0	197	100 0	199	100 0	207	100 0	400	100 0	207	100 0	193	100 0
0–30	138	17 2	31	15 7	34	17 3	35	17 6	38	18 4	68	17 0	37	17 9	31	16 1
37–60	347	43 4	89	45 2	86	43 7	92	46 2	80	38 6	151	37 7	85	41 1	66	34 2
61 <	315	39 4	77	39 1	77	39 1	72	36 2	89	43 0	181	45 2	85	41 1	96	49 7

The code number of the ampoule containing the contrast medium, all relevant data about the patient, previous urographies, drug intake and side effects were written on a record form for each patient From the record form, the data were punched on cards and analysed in a computer Besides arranging the tables, the data processing included statistical comparison of side-effect frequencies in different groups, using the chi-square test In the analysis of data, side-effects that appeared after compression had been applied and disappeared again when the compression was released, were not taken into account

Results

The age and sex distribution of the patients receiving the different contrast media appear in Table 1

Side-effects in relation to contrast media In series I, 10 6 per cent of the 800 patients presented one or more side-effects, sensation of warmth not included In series II, the corresponding percentage was 10 3 for 400 patients

Table 5

Age and sex distribution, frequency of sensation of warmth and side-effects for all patients P per cent of patients with one or more side-effects, PW per cent of patients with a sensation of warmth Patients with both a sensation of warmth and side-effects, are included in both columns

Group	Series I			Series II		
	No	P	PW	No	P	PW
Females all	350	9 4	25 1	164	12 8	48 2
Age 0–30	79	15 2	35 4	34	17 6	58 8
Age 31–60	137	11 7	26 3	70	15 7	48 6
Age 61 and more	134	3 7	17 9	60	6 7	41 7
Males all	450	11 6	16 0	236	8 5	31 4
Age 0–30	59	13 6	18 6	34	8 8	41 2
Age 31–60	210	13 8	21 4	81	11 1	43 2
Age 61 and more	181	8 3	8 8	121	6 6	20 7
Total	800	10 6	20 0	400	10 2	38 2
Age 0–30	138	14 5	28 3	68	13 2	50 0
Age 31–60	347	13 0	23 3	151	13 2	45 7
Age 61 and more	315	6 3	12 7	181	6 6	27 6

cally, the difference between the lowest and highest incidence was significant in both cases ($p<0\ 05$) In series I, the lowest and highest incidence appeared in two succeeding months, August and September

Side effects in relation to drug intake Table 3 gives the frequencies of side-effects in patients grouped according to their intake of drugs Patients who received both antihistamine and atropine, or one of these in combination with other drugs, were referred to the group designed as 'others' The first computer output indicated a significantly lower incidence of side-effects in patients who had been premedicated with atropine

Another computer program that revealed the age distribution of the patients who had been premedicated with atropine, and of the patients who had received no drugs before the examination, was then used A repeated examination of the data by this program, revealed that the age distribution among patients who had received atropine, was quite different from that of patients who had taken no drugs during the last 72 hours A greater proportion of the patients (63 out of 105) in the group premedicated with atropine only, were older than 60 years (Table 4) In the group of patients receiving no drug before the examination, only 112 out of 418 were older than 60 years

Side-effects in relation to age and sex In Tables 4 and 5 appear the frequencies of side-effects in relation to age and sex of the patients Table 5 includes all patients

Table 3

Frequency of side-effects, related to the drug intake

Drug intake	Series I		Series II	
	Number of patients	Per cent of patients with side-effects	Number of patients	Per cent of patients with side-effects
No drug last 72 hours	418	12 0	185	10 3
Atropine only	105	4 8	90	6 7
Antihistamine only	41	12 2	30	20 0
Others	236	10 6	95	10 5

Table 4

Age and sex distribution, and frequency of side-effects, for patients who received no drug before the examination, and for patients premedicated with atropine, but no other drugs P per cent who had one or more side effects

Group	Series I				Series II			
	No drug		Atropine only		No drug		Atropine only	
	No	P	No	P	No	P	No	P
Females, all	166	12 7	42	4 8	72	11 1	30	13 3
Age 0–30	61	14 8	1	0	24	12 5	2	0
Age 31–60	70	15 7	14	7 1	32	15 6	10	20 0
Age 61 and more	35	2 9	27	3 7	16	0	18	11 1
Males, all	252	11 5	63	4 8	113	9 7	60	3 3
Age 0–30	45	15 6	5	0	18	11 1	5	0
Age 31–60	130	12 3	22	13 6	53	13 2	8	0
Age 61 and more	77	7 8	36	0	42	4 8	47	4 3
Total	418	12 0	105	4 8	185	10 3	90	6 7
Age 0–30	106	15 1	6	0	42	11 9	7	0
Age 31–60	200	13 5	36	11 1	85	14 1	18	11 1
Age 61 and more	112	6 3	63	1 6	58	3 4	65	6 2

Side-effects in relation to month of examination On the average, 60 urographies were carried out each month Because of the randomisation of contrast media, approximately 15 patients received each contrast medium every month in series I Correspondingly, every month approximately 30 patients received each of the two contrast media used in series II In both series, the incidence of a sensation of warmth and of other side-effects was highly variable from month to month The percentage of patients with side-effects, except a sensation of warmth, fluctuated from month to month between 3 8 and 20 4 in series I, and between 2 4 and 22 9 in series II Statisti-

The recordings of many of the side-effects in urography depend on a description made by the patient This limits the accuracy in observing this kind of side-effects, and is also a source of variation in the results given in different reports

In series I, the overall frequency of side-effects was 10 6 per cent The corresponding figure in series II was 10 3 per cent. The findings in series I were corroborated in series II, except for the differences due to the different contrast media This indicates that the technique used has given reproducible results

No significant differences in the overall incidence of side-effects were found between the 4 different media tested, but the sodium-calcium-magnesium metrizoate gave a significantly higher incidence of a sensation of warmth than the other contrast media Since the incidence of this reaction was approximately the same for the pure meglumine salts of metrizoate and diatrizoate, the sensation of warmth seems to be related to the cationic part of the contrast medium The difference between meglumine metrizoate and meglumine-calcium metrizoate was not statistically significant Thus calcium can at least not be the only contributor to the higher incidence of a sensation of warmth found for sodium-calcium-magnesium metrizoate Another possible contributor is sodium, wellknown from angiographic examinations to cause more sensation of warmth than meglumine

The surprisingly great variation in the incidence of side-effects in different months, emphasizes the necessity of using different contrast media in the same time period, and after a randomised scheme, when different contrast media are compared with respect to side-effects Some of the variations from month to month may have been due to differences in the sample of patients, but other factors are probably also contributing

The incidence of side-effects in relation to drug intake is included, because, in the opinion of the present authors, it demonstrates in what way erroneous results may turn up, if the patients compared are not properly selected From Table 3, it might have been reasonable to believe that premedication with atropine would have reduced the incidence of side-effects like nausea, because of the anticholinergic action of the drug But as revealed by Table 4, among the in-patients at the hospital, who were given atropine, a majority were older than 60 years, and therefore belong to a group who has less side-effects than other patients From these data, no conclusion can therefore be drawn about the influence of atropine on side-effects produced by the contrast medium

Patients who previously had one or more urographies, had more frequently a sensation of warmth than patients examined for the first time This is difficult to explain One possibility is that patients who had had symptoms at a previous urography may have expected the same symptoms to occur the next time and therefore more readily felt them SHEHADI & MASHKIN found a higher incidence of side-effects in patients who previously had had side-effects after a contrast medium injection

Table 6

Frequency of side effects (in per cent) in patients having their first urography, and in patients with one or more previous urographies No = number of patients

Side-effect	Series I		Series II	
	No previous urography No = 581	Previous urography No = 219	No previous urography No = 255	Previous urography No = 145
All except a sensation of warmth	10 3	11 4	8 2	13 8
Sensation of warmth	17 6	26 5	32 2	49 0
Nausea	6 2	8 2	5 1	9 7
Urticaria	2 1	0 9	1 6	3 4
Other allergic reactions	1 4	1 4	0 4	0 7
Other reactions	2 1	1 4	1 6	1 4

while Table 4 includes only those who had received no drugs, and those who had received atropine as the only drug No significant differences were found between the frequencies of side-effects for all female and all male patients

The overall incidence of side-effects was lower for patients aged 61 or more than for the younger patients (Table 5) The difference was statistically significant both in part one ($p<0\ 01$) and in part two ($p<0\ 05$) The incidence of a sensation of warmth was also significantly lower in the highest age group in both series ($p<0\ 01$)

For patients receiving no drug (Table 4) the overall incidence of side effects was also lowest in patients aged 61 and more However, because of the relatively small number of patients who had received no drug, the difference was only statistically significant ($p<0\ 05$) in series I

Side-effects in relation to previous urography In both series, the overall frequency of side-reactions other than sensation of warmth, was lower in patients having their first urography, than in patients who had had one or more previous urographies (Table 6) The same tendency was found for a sensation of warmth and nausea Statistically, the difference was significant only for a sensation of warmth ($p<0\ 01$) in both series

Discussion

In some materials up to 80 to 90 per cent of the patients have been reported to experience some sensation, warmth included, to urography when questioned thoroughly (BRASCH et coll 1970, BEALES et coll) In most reports, however, side-effect frequencies of 5 to 20 per cent is given (SHEHADI & MISHKIN, WITTEN et coll , DE LANGEN & HERMANS 1973, GRAEBNER & BAYINDIR, FREDE LARSEN et coll , RITCHIE & BURRAGE 1969, MACHT et coll)

The recordings of many of the side-effects in urography depend on a description made by the patient This limits the accuracy in observing this kind of side-effects, and is also a source of variation in the results given in different reports

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The surprisingly great variation in the incidence of side effects in different months, emphasizes the necessity of using different contrast media in the same time period, and after a randomised scheme, when different contrast media are compared with respect to side-effects Some of the variations from month to month may have been due to differences in the sample of patients, but other factors are probably also contributing

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Conclusion

If the incidence of side-effects at urography is compared for different contrast media, it is essential that they be used in the same time period, and after a randomized scheme, as the frequency of side-effects may differ greatly from month to month A sensation of warmth was most frequent for the sodium-calcium-magnesium metrizoate, but the percentage of patients who had one or more side-effects except a sensation of warmth, was not significantly different for any of the 4 contrast media

In general, patients of 61 years and more had a lower incidence of side-effects than younger patients A sensation of warmth was more frequent in patients who had previously had one or more urographies than in patients examined for the first time The latter findings were corroborated in 400 urographies, where two other batches of sodium-calcium-magnesium metrizoate were used

We regret the untimely death of Dr Å Mellbye soon after completion of the manuscript

SUMMARY

The incidence of side-effects produced by meglumine diatrizoate and meglumine , meglumine-calcium , and sodium-calcium-magnesium metrizoate, was compared in 800 urographies Patients older than 60 years seem to have less side effects than younger patients The incidence of sensation of warmth seems to be higher in patients who have had previous urographies, compared to those who are examined for the first time The incidence of this effect is higher for the sodium-calcium-magnesium salt of metrizoate, than for other salts of metrizoate

ZUSAMMENFASSUNG

Das Vorkommen von Nebenwirkungen, die durch Meglumin-Diatrizoat und Meglumin-, Meglumin-Kalzium- und Natrium-Kalzium-Magnesium Metrizoat hervorgerufen werden wurde bei 800 Urographien verglichen Mehr als 60 Jahre alte Patienten scheinen weniger Nebenwirkungen als jungere Patienten zu haben Das Vorkommen von Warme Empfindungen scheint bei Patienten, bei denen zuvor Urographien vorgenommen worden waren, haufiger zu sein verglichen mit Patienten die zum ersten Mal untersucht wurden Das Vorkommen dieser Nebenwirkung ist bei Natrium Kalzium-Magnesium Salz von Metrizoat haufiger als bei anderen Salzen von Metrizoat

RÉSUMÉ

[illegible] par le diatrizoate [illegible] lcium-magnésium [illegible] voir moins d effets secondaires que les patients plus jeunes La sensation de chaleur semble plus fréquente

chez les malades qui ont eu des urographies auparavant, par rapport a ceux qui sont examines pour la première fois La fréquence de cet effet est plus élevée pour le sel de sodium–calcium–magnesium de métrizoate que pour les autres sels de metrizoate

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Book review

RÖNTGENOLOGISCHE DIFFERENTIALDIAGNOSTIK Band I Thoraxorgane, Teil 1 Lunge und Pleura By W Teschendorf, H Anacker and P Thurn 824 pages with 769 figures and 31 tables Georg Thieme Verlag, Stuttgart 1974 Price DM 298 —

The first edition was published in 1931 and twenty years have passed since the fourth edition appeared The fifth edition is now available, improved and modernized and with new illustrations The clinical concept that the differential diagnosis is based upon clinical findings and history has been continued from previous editions Also the pathology is included to a certain extent There are more than 1 200 separate illustrations many of good quality but too many of the original films seem to have been exposed with a rather low kilovoltage This fact in combination with a high contrast in the reproduction and a positive technique may confuse and does not represent an ideal

From an educational point of view the reproduction that gives the appearance of the original film is to be preferred The radiologic experience is to a great extent built upon a visual memory and a positive view may give some anatomic information but not the real visual impression of the original film Especially for the diagnosis of pulmonary lesions, which involves different film half tones, the conditions are critical A standardization of the presentation of chest films in the literature seems to be desirable especially with regard to teaching The tomograms presented are illustrative

A complete examination of the lungs always includes a lateral view and also often oblique ones It is somewhat surprising that rather few lateral views are presented Blow-up details are frequent and of some value, but special projections might give more information It is also surprising that high kilovoltage technique and penetrated films of the heart region have not been used

There are several informative tables with statistics of various diseases regarding frequency, etiology, distribution of ages, differential diagnostic facts, etc The characteristic lesions are classified as in botanical handbooks facilitating the diagnostic analysis A logical borderline exists between the chapters on lesions with increased attenuation and those on reduced attenuation such as cysts, emphysema etc These two main parts of the work are about similar in size This 800 page book is somewhat heavy and uncomfortable to handle and it may be discussed if not a division into two parts had to be preferred

The appearances of the lesions are not described on the basis of their morphologic background but as spot- or streak-like fine grained or fine-meshed rarified, etc , which reduces the value

Tuberculosis has been reduced in importance the world over, but this fact is not reflected in the text as much space is still devoted to this disease Today more attention should perhaps be paid to tropical lesions The industrial chest diseases which have increased in importance, are thoroughly penetrated The use of isotopes for diagnostic purposes is rather scantly touched upon However the few cases presented are instructive

The references are extensive, also including reports of a more peripheral character

The book gives a complete survey of pulmonary diseases The clinical and therapeutical information is of considerable value but it can hardly be said that the radiologic technique and the description of the radiologic appearance of the pulmonary lesions correspond to the requirements of today

Ove Mattsson

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IMPLANTATION METASTASIS AFTER PERCUTANEOUS TRANSTHORACIC NEEDLE ASPIRATION BIOPSY

W N SINNER and J ZAJICEK

Percutaneous transthoracic needle aspiration biopsy is used increasingly in the diagnosis of pulmonary lesions It is a fairly simple procedure and causes the patient little discomfort The complication rate is low and the diagnostic accuracy is good In many centres a wide range of indications are accepted (DAHLGREN & NORDENSTRÖM 1966, LALLI et coll 1967, WALLS et coll 1974)

One complication which might conceivably limit the use of this method is spread of malignant cells along the needle track In order to assess the likelihood of this possibility the results of follow up in 2 726 cases who had had percutaneous transthoracic needle biopsy of pulmonary lesions was reviewed The interest was focused on cases in which a malignant lesion was diagnosed On the basis of the results the risk of tumour spread via the needle track is discussed

Method

Transthoracic needle aspiration biopsy is performed according to the method of DAHLGREN & NORDENSTRÖM, which will be described briefly The outer diameter of

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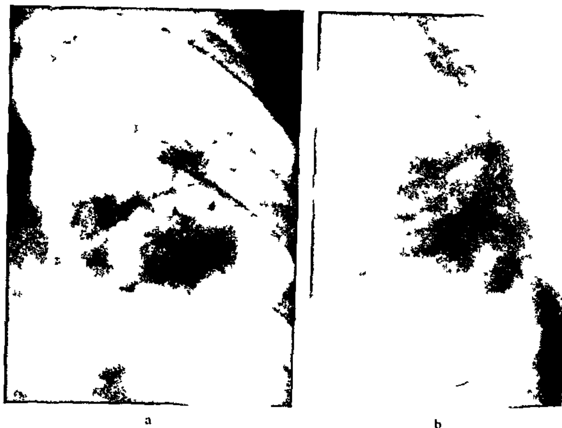


Fig 1 75 year old man Tumour with a diameter of 7 cm in the ap cal segment of the l ft lo er lobe a) A p b) lateral view

the needles is 0 9 to 1 1 mm (20 to 18 gauge) the length 9 12 or 16 cm depending on the site of the lesion The needles have sharp bevelled tips and edges and are equ pped with an obturator After local anaesthesia the skin is nicked with a special perforation needle at a site which is not necessarily directly over the lesion For peripheral lesions near the thoracic wall a more tangential approach is preferred

Under television monitoring the biopsy needle is introduced in the direction of the central beam close to the upper costal margin in order to avoid the intercostal artery Sometimes when the needle enters the lesion an increased resistance is felt and small movements may displace the lesion The exact positioning of the needle is checked by TV monitoring simultaneously in the sagittal and in the lateral plane When the needle tip is in the desired position (preferably at the periphery of the lesion since the centre is often necrotic) the needle is rotated in order to detach cellular material The obturator is then withdrawn A disposable syringe (10 to 20 ml) is attached to the needle and aspiration is performed by retraction of the piston After the aspiration the piston is released and the needle is withdrawn The syringe is now disconnected from the needle filled with air and reconnected

The aspirated material in the needle is expelled onto a clean glass slide Smears are prepared and are immediately examined cytologically If the result is negative

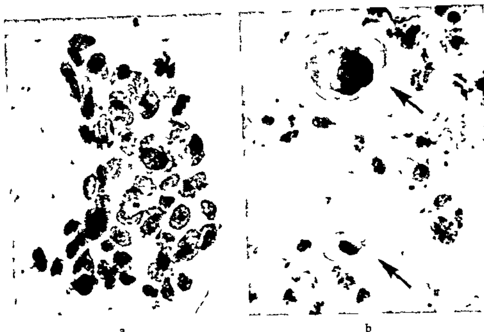


Fig 2 Same case as in Fig 1 Needle aspirate a) A cluster of poorly differentiated squamous carcinoma cells b) Two carcinoma cells (→) with differentiation towards squamous epithelium Hematoxylin-eosin ×465

(no evidence of malignancy) the biopsy is repeated At least three aspirations from different parts of the lesion are performed before a negative result is accepted as conclusive In the present series the numbers of needle biopsy per patient varied from one to five, but usually two were performed

Results

During the period January 1961 to April 1974, 5 300 biopsies were performed on 2 726 patients The cytologic reports indicated a malignant lesion in 1 264 cases and possible malignancy in 75 Of the 1 264 malignant lesions, 1 064 were primary pulmonary tumours and 200 were metastatic

Neoplastic growth (implantation metastasis) was clinically observed at the site of needling in one patient whose clinical history is now presented

Case report

Th...
in ...
wit ... was performed using a dorsal approach The cytology showed a moderately differentiated squamous cell carcinoma consistent with primary

bronchogenic carcinoma (Fig 2) No immediate complications of the biopsy, such as pneumothorax or local bleeding, occurred The tumour was considered inoperable

Five months later the patient reported for routine out-patient check-up A palpable soft tissue mass measuring about 2 cm in diameter was found dorsolaterally, corresponding to the puncture site The mass was excised and microscopy revealed a squamous cell carcinoma metastasis, presumably from the primary tumour Neither hilar nor mediastinal metastases were found, but the primary tumour had increased considerably in size

In 4 other cases in which malignant neoplastic growth in the lung was found at biopsy a pleural effusion occurred immediately after biopsy Empyema developed in 2 of these patients In none of these 4 cases did microscopy of the aspirated fluid reveal tumour cells

Discussion

Implantation metastases in connection with percutaneous needle aspiration biopsy have occasionally been reported CRILE & HAZARD (1951) described a case in which a Silverman needle had been used to obtain a tissue core from a papillary carcinoma of the thyroid Dissemination of malignant cells along the needle track was observed by CACHIN et coll (1969) following biopsy of a lymph node metastasis of the neck The size of the needle was not specified ACKERMAN & WHEAT (1955) reported a case of squamous cell carcinoma and one of malignant melanoma in which tumour growth along the needle track could be demonstrated 16 and 19 days respectively after a needle biopsy of the lesion (size and type of needle not stated) In 4 cases of prostatic carcinoma local extension of the tumour was attributed to transperineal thick-needle biopsy performed 13 to 16 months previously (CLARKE et coll 1953, GOLDMAN & SAMELLAS 1960, BURKHOLDER & KAUFMAN 1966, LABARDINI & NESBIT 1967) Dissemination of tumour cells through the needle track of percutaneous transthoracic biopsy has been documented in two previous cases (DUTRA & GERACI 1954, WOLINSKY & LISCHNER 1969)

A relevant point in these reports is that when the type and size of the needles were stated they were of wide bore (Vim–Silverman or Franklin–Silverman) needles A search of the literature has revealed no definite reports of local tumour extension caused by fine-needle (18 to 20 gauge) aspiration biopsy

ENGZELL et coll (1971) have demonstrated that carcinoma cells may appear in the needle track after percutaneous biopsy with an 18-gauge needle in rabbits with popliteal metastases from transplantable V × 2 carcinoma In these experiments the fluid that seeped through the needle puncture in the capsule of the lymph node always contained malignant cells ZAJICEK (1970) observed that blood escaping along the needle track after needle biopsy of mammary carcinoma could contain malignant cells On the other hand, a clinical follow up of 157 patients with pleomorphic adenoma of salivary glands and of 469 patients with prostatic carcinoma, all diagnosed by fine needle (22 gauge) biopsy, revealed no evidence of recurrence or local extension of tumour growth that could be attributed to the biopsy (ENGZELL et coll)

A possible explanation for these contrasting results in regard to tumour spread is the difference in the nature of the material aspirated with thick and with fine needles

Carcinoma cells aspirated through fine needles are usually without notable admixture of stroma, but when wide-bore needles are used the yield usually consists of sizeable stroma fragments containing carcinoma cells It is possible that such detached fragments of stroma more readily give rise to tumour growth in the needle track than do clusters of carcinoma cells without their stroma

In the present series of 1 264 pulmonary malignancies the size of the biopsy needles ranged from 0 9 to 1 1 mm (20 to 18 gauge) In only one case was malignant growth found in the needle track The risk of tumour spread when needles of these dimensions are used appears therefore to be almost as insignificant as that with 0 6 mm (22 gauge) needles

The possibility that tumour cells may spread through the needle track into the pleural cavity also merits discussion BERGER et coll (1972) reported two cases in which pleural effusion developed immediately after biopsy Cytology of the fluid revealed 'atypical cells with tumour cells consistent with malignancy' The type of needle was not stated It was assumed that these cases represented dissemination of malignant cells due to the biopsy Another cytopathologist (NAYLOR), however, reviewed the same cytologic material and stated that in both cases he would have reported the pleural fluid as negative for malignancy

The frequency of pleural carcinosis in surgically treated carcinoma of the lung is approximately 1 per cent whether or not the patients have undergone needle biopsy previously (HAUSSER 1965) This suggests that even in non-surgically treated pulmonary carcinoma the appearance of progressive pleural carcinosis or of malignant cells in pleural fluid need not be attributed to the biopsy

Increased amount of fluid in the pleura was found in 4 of the 1 264 patients in whom the biopsy revealed pulmonary malignancy Cytology of the aspirated fluid demonstrated no tumour cells, nor was tumour growth manifest in the pleural cavity during the follow up period, which suggests that biopsy does not cause dissemination of tumour cells into the pleural cavity In this connection it is perhaps relevant that, when the pulmonary lesion was close to the thoracic wall, special care was always taken to introduce the needle tangentially The resultant prolongation of the needle track through the lung may have reduced the possibility of cells from the tumour reaching the pleural cavity However, to what extent this procedure has prevented malignant seeding of the pleural cavity is unknown

Haematogenic spread of the tumour with resultant shortening of survival times is another conceivable complication VON SCHREEB et coll (1967) analyzed the five-year survival rates in 77 patients who were operated upon for renal carcinoma following needling and injection of contrast medium into the tumour Comparisons with 73 controls whose tumours were not needled revealed no significant differences in survival rates

In a comparative follow up over 5 years (ROBBINS et coll 1954) and over 15 years (BERG & ROBBINS 1962) of 370 patients who underwent surgery for mammary carcinoma after needle biopsy and of 370 controls in whom the diagnosis had been

established by other means, identical survival rates were found in the two groups They therefore concluded that the biopsy had no deleterious effect on the survival in mammary carcinoma

SINNER (1973) reported the follow-up of 106 patients in whom peripherally located malignant pulmonary lesions less than 2 cm in diameter had been diagnosed by transthoracic biopsy. The five-year survival rate was 42 per cent in primary carcinoma and 32 per cent for patients with solitary metastasis of extra-pulmonary tumours

Similar figures have been published from series of pulmonary carcinoma without transthoracic biopsy CHURCHILL et coll (1958) reported 42 per cent five-year survival in 38 patients with accidentally detected, asymptomatic malignant 'coin lesions' and 28 per cent in 220 surgically treated patients with other malignant lesions Among 952 cases reported by PAULSON & URSCHEL (1971) 45 per cent were considered operable and 41 per cent proved to be resectable After 5 years 35 per cent of the first group and 45 per cent of the second were still alive Less than 2 per cent of the patients with only an exploratory thoracotomy survived for 5 years

From the similarity of the figures cited with survival rates after percutaneous transthoracic needle aspiration biopsy it may be concluded that this procedure does not affect the survival in pulmonary carcinoma and that it may reasonably be used for diagnostic purposes when indicated

SUMMARY

The risk of tumour spread at aspiration biopsy of pulmonary tumours through the needle track has been analyzed by reviewing the case histories of 1 264 patients with a malignant tumour demonstrated by needle biopsy Only in one case did metastatic tumour growth develop at the site of the biopsy The history of this case is presented and the available literature on the subject discussed

ZUSAMMENFASSUNG

Das Risiko der Tumorverbreitung durch den Einstichskanal bei der Aspirationsbiopsie von Lungentumoren wurde bei Durchsicht der Krankengeschichten von 1264 Patienten, bei denen ein maligner Tumor durch Nadelbiopsie nachgewiesen worden war, analysiert Nur in einem Fall entwickelte sich ein metastatischer Tumor an der Stelle der Biopsie Die Geschichte dieses Falles wird prasentiert und die betreffende Literatur diskutiert

RÉSUMÉ

Les auteurs ont étudié le risque de dissémination tumorale au cours de la biopsie par aspiration de tumeur pulmonaire le long du trajet de l'aiguille en réétudiant les observations de 1264 malades atteint de tumeur maligne mise en évidence par biopsie à l aiguille C'est seulement dans un cas qu'une tumeur métastatique s'est développee sur le siege de la biopsie Les auteurs présentent l'observation de ce cas et examinent la littérature existant sur ce sujet

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MULTIPLE EXPANDING RENAL LESIONS

OLLE OLSSON

Exploratory surgery for expanding renal lesions has been widely used and is still common in many centres A representative example is given in a report by WITTEN et coll (1963) who, in a discussion of the value of nephrotomography in distinguishing between renal tumours and cysts, make it 'emphatically clear that surgical exploration is not to be abandoned in questionable cases' This measure was employed in 82 of 330 cases

Such exploration carries certain risks Thus KROPP et coll (1967) reviewed a series of 126 consecutive adult patients subjected to surgical exploration for renal masses which proved to be cystic There were two postoperative deaths, giving a mortality rate of 1 6 per cent Surgical complications occurred in 38 cases and nephrectomy was performed in two of these PLAINE & HINMAN (1965) in a report on surgical exploration of 123 patients with asymptomatic renal masses, found a cyst in 102 patients One of these patients died, and in two patients cerebrovascular accidents occurred, resulting in permanent disability In addition, in 11 cases microscopy revealed that healthy kidneys had been removed, either because the benign nature of the lesion could not be determined at operation, or because of uncontrollable hemorrhage

Other objections have been raised to exploratory intervention Thus ROBSON (1963) in a report on renal carcinomas noted a significant improvement in survival

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WALLS J. W., THORNBURY J. R. and NAYLOR B.: Pulmonary needle aspiration biopsy in the diagnosis of Pancoast tumors. Radiology 111 (1974), 99.
WOLINSKY H. and LISCHNER M. W.: Needle track implantation after percutaneous lung biopsy. Ann. intern. Med. 71 (1969), 2.
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which concerns those expanding lesions of the renal parenchyma which are usually single and unilateral, although occasionally they may be multiple and bilateral

Bilateral expanding lesions are less rare if their frequency is estimated from a material which includes angiography In Lund, over a period of a few years, about 25 cases were encountered, representing a rich variety of combinations carcinoma on one side, simple cyst in the contralateral kidney, single cyst on one side, multiple cysts on the other, multiple cysts in both kidneys, carcinoma in both kidneys, pelvic carcinoma in one kidney, carcinoma in the other, angiomyolipoma and cysts in one kidney, single cyst in the other, carcinoma in one kidney, metastases in the contralateral kidney, etc

Since this institution is part of a university hospital, and several of the patients have been referred from other hospitals, it is impossible to give a frequency rate for such lesions Suffice it to say that they are unusual but common enough to necessitate special consideration

The most common combination in the present material is carcinoma in one kidney, simple cyst in the other In only one of 10 patients with this combination did the abnormality, demonstrated at urography, suggest malignant tumour In this case the kidney pelvis was displaced and deformed, the wall of the pelvis was infiltrated, and the tumour protruded into the cavity of the pelvis In all the other carcinomas there was either mere displacement of the kidney pelvis or no abnormality at all The same applied to simple cysts

Carcinoma was unexpectedly discovered in 2 patients at angiography, performed because of an expanding lesion in the contralateral kidney found at urography. The lesion was found to be a cyst A small carcinoma discovered at angiography in the other kidney could not be identified on the urograms even at retrospective analysis

Six cases of bilateral renal expanding lesions in various combinations are presented

Case reports

Bilateral expanding lesions

Case 1 Female, aged 61 Coronary thrombosis six months previously Urography was carried out because of polycythaemia [illegible] caudal half of left kidne[illegible] medium bilaterally Sl[illegible] sion of calices in midc[illegible] kidney (Fig 1 a, b) Selective angiography Left kidney (Fig 1 d) Large slightly irregular carcinoma in caudal half, rich in pathologic vessels Right kidney (Fig 1 c) Carcinoma with slightly irregular outline and [illegible] vascularity [illegible]

rate through avoiding exploratory measures, and instead using a radical surgical approach including removal of the renal tumour and adjacent tissue en bloc together with the lymphatics. WAHLQVIST (1969) further stressed this point and in view of the risk of tumour spread, advocated that primary operation for renal carcinoma should comprise the removal of the entire kidney, homolateral suprarenal gland perirenal fat tissues, retroperitoneal lymph nodes along the aorta, the inferior vena cava and the homolateral common iliac vein and artery. These views all stress the importance of an unequivocal pre-operative diagnosis with the accurate differentiation of expanding lesions in the kidney. The crucial problem is to distinguish renal carcinoma from simple cyst. To a great extent the solution is based on high quality angiography.

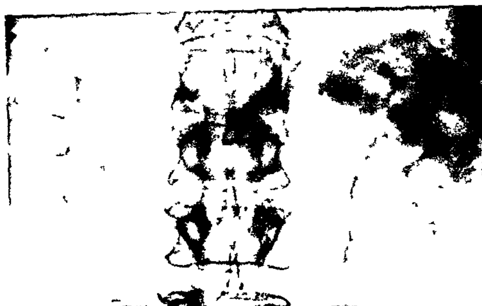
The recognition of a tumour without evidence of an expanding lesion at urography or pyelography has become increasingly common. At urography, minor deformities of the calices, the renal pelvis, or the outline of the kidney may be difficult to distinguish from normal anatomic variations. These difficulties may easily be exemplified in any material of possible expanding renal lesions. They are particularly well demonstrated in patients with multiple expanding lesions in one or both kidneys.

Multiplicity of renal expansive lesions bilaterally has attracted some attention in the literature (see for example, KAHRMANN & WERNER 1973, OLSSON 1974). Interest has been focused mainly on malignant tumours of bilateral incidence. The rarity of this phenomenon has been pointed out in several reviews with reports on similar or dissimilar histogenesis of the tumours (see literature presented in GILLIS et coll. 1971). The question of primary versus secondary bilaterality has also been considered in detail. Nevertheless, it seems that the roentgenologic diagnostic difficulties inherent in cases with multiple expanding lesions have not been fully appreciated.

Some renal expanding lesions are often bilateral: polycystic kidneys, systemic disorders, and metastases. Nephroblastoma (Wilms' tumour) is bilateral in children in 3.6 per cent of cases. It was pointed out by SCOTT (1955) that this tumour may also be encountered in adults although bilaterality has not been observed after the age of six years.

In systemic disorders such as lymphogranulomatosis, renal involvement may be bilateral. *Metastatic spread of tumours to one or both kidneys from other organs* are on record (SHIMKIN et coll. 1972, ZINCKE & FURLOW 1973). After the liver, lungs, bones and adrenals, the kidneys represent the commonest site of metastases, usually from pulmonary or mammary neoplasms (BOSNIAK et coll. 1969). As a rule, these metastases are multiple, bilateral and small. Four cases of metastatic neoplasm in the kidney were reported by BOSNIAK et coll., all hypovascular at angiography and without definite tumour vessels. Mention should also be made of tuberous sclerosis. In this disease entity, multiplicity of tumours in one or both kidneys is common. At autopsy of 9 patients, GOLJI (1961) found renal neoplasms in 8; 7 of these had numerous tumours in both kidneys.

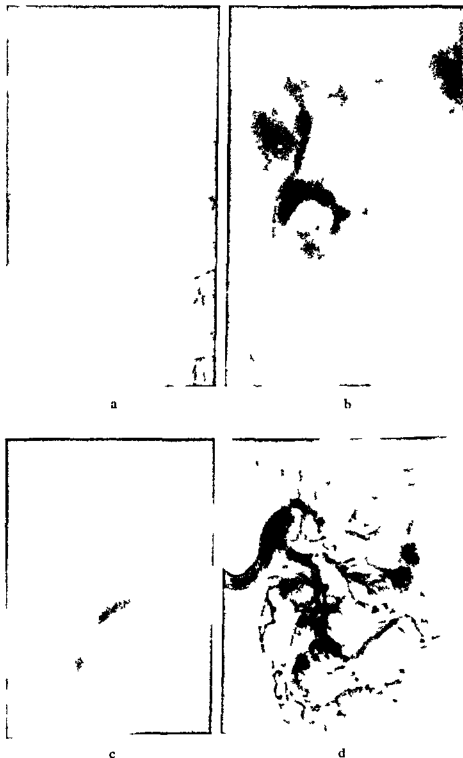
The foregoing types of lesion will not be considered further in the present report,



a



b c d



a b

c d

Fig 1 a ... kidney and in central part of ... only fe v patholog c vessels i ... e richly vascularised carcinoma in caudal part



Fig. 4 a b) Urography Marked impress on in and compression of caudal part of left pelvis and medial part of right pelvis c d) Selective angiography bilaterally Cyst in middle of right kidney Another cyst in cranial pole Large cyst in caudal medial part of left kidney Somewhat larger cyst medial-dorsally in cranial part

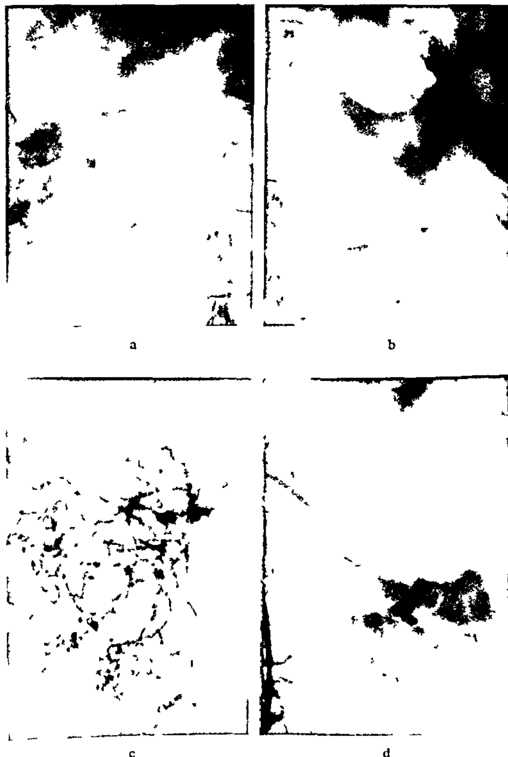


Fig 3 a b) Urography Marked displacement caudally of left kidney pelvis and impression in superior part Compression of caudal part of right kidney pelvis c d) Selective angiography, bilaterally Large, richly vascularised carcinoma in right kidney Only cranial pole is free of tumour Large cyst in cranial part of left kidney

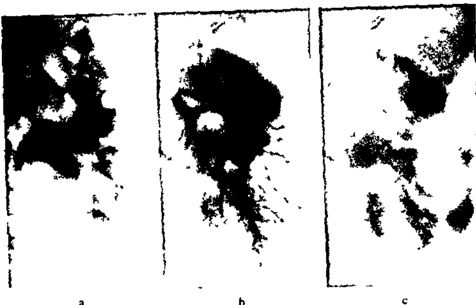


Fig 6 a) Urography Slight lateral displacement of caudal part of left kidney pelvis b) Selective angiography, left kidney b) Arterial, c) venous phases Fairly well defined hemangioma in central part of kidney, conforming to displacement of kidney pelvis Small carcinoma with pathologic vascularity in cranial pole (arrows)

Unilateral expanding lesions

Case 4 had multiple cysts in each kidney Unilateral multiplicity of this type is not rare In addition to 2 or more simple cysts in one kidney, the present series contains cases with cysts of different kinds in one and the same kidney, the combinations of simple cyst and carcinoma, of different types of cysts and carcinoma, of concurrent hemangioma and carcinoma Four cases are presented to illustrate these diverse combinations

Case 5 Male, aged 70, with hematuria Urography The patient had only one kidney, the left one, with a large circumscribed mass in its caudal part

Selective angiography Left kidney (Fig 5) Large cyst in caudal half of kidney, well demarcated carcinoma 5 cm in diameter in cranial pole

Case 6 Male, aged 66, with hematuria Urography (Fig 6 a) Normal kidney size and shape Normal excretion of contrast medium Caudal calices of left kidney slightly displaced laterally and slightly compressed Selective angiography Left kidney (Fig 6 b, c) Wide irregular arteries and veins—hemangioma—in caudal, central part of kidney Tumour 2 cm in diameter in cranial pole of kidney which does not affect the shape of cranial kidney pole Slightly pathologic vascularity The diagnosis of hemangioma in caudal central part of left kidney and carcinoma in cranial pole of the same kidney, was confirmed at operation

Case 7 Female, aged 58 with hematuria Urography Mass lesion in cranial part of right kidney suggestive of tumour because of irregularity of the lesion Selective angiography.

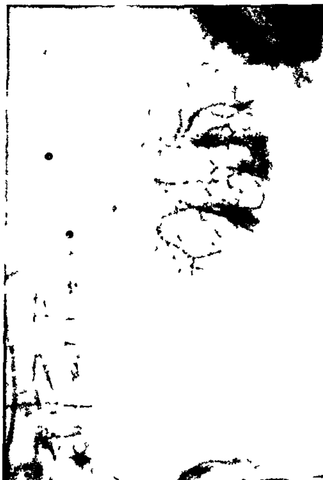


Fig 5 Selective angiography of solitary left kidney Large well defined avascular, expanding lesion caudally—cyst cranially—well circumscribed expanding lesion 5 cm in diameter with moderate pathologic vascularity—carcinoma

Case 2 Male, aged 51 with hematuria Urography Left sided renal tumour with infiltration of wall of renal pelvis (Fig 2 a) Right side no evident abnormality Selective angiography Left kidney (Fig 2 c, d) Two renal arteries, large carcinoma with wide arteriovenous fistulas Right kidney (Fig 2 b) Fairly large carcinoma centrally in caudal part of kidney

Case 3 Female, aged 75, with hematuria Urography (Fig 3 a b) Large circumscribed expanding lesion in cranial part of left kidney (On re-examination of the films, a mass was also recognized in the slightly enlarged right kidney) Selective angiography Right kidney (Fig 3 c) Large, richly vascularized carcinoma Left kidney (Fig 3 d) Large avascular lesion in cranial part, cyst At operation both roentgenologic diagnoses were confirmed

Case 4 Male, aged 63, with hematuria Urography (Fig 4 a, b) Both kidneys slightly enlarged and irregular in shape Normal excretion of contrast medium Right kidney pelvis [illegible] pelvis compressed from [illegible] 4 c) Expanding lesion, [illegible] l branches and without [illegible] pathologic vessels Lesion of similar appearance medially in cranial pole measuring 3 cm × 3 5 cm Left kidney (Fig 4 d) Mass 6 cm × 6 cm in superior posterior part and mass 4 cm × 4 cm in caudal medial part The diagnosis, cysts in both kidneys was confirmed by puncture of the cysts

fined to one kidney alone, since expanding lesions involving both kidneys are by no means rare, and a lesion of another kind may affect the other kidney Renal carcinoma may metastazise to the other kidney, as was the case in at least one patient in the present material

Masses, whether tumours or cysts, may be impossible or difficult to detect with certainty at urography One kidney may harbour one, two or more lesions of differing pathology Only one of these may be detectable at urography, whereas a detailed analysis can be made of all of them at angiography

SUMMARY

Unilateral or bilateral multiplicity of expanding lesions in the kidneys is not too unusual and different types of lesions may be combined This stresses the need for detailed angiography of both kidneys in order to establish an exact diagnosis

ZUSAMMENFASSUNG

Unilaterale oder bilaterale Multiplizität expandierender Läsionen in den Nieren sind nicht besonders ungewöhnlich, und verschiedene Typen von Läsionen konnen kombiniert vorkommen Das weist auf die Notwendigkeit einer detaillierten Angiographie beider Nieren hin, um eine exakte Diagnose zu erreichen

RÉSUMÉ

La multiplicité unilatérale ou bilaterale des lesions expansives dans les reins n'est pas exceptionnelle et différents types de lésion peuvent être associés Ceci souligne la necessité d une angiographie détaillee des 2 reins pour etablir un diagnostic exact

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Ge [illegible] May (1973), 145

KROPP K A, GRAYHACK J T, WENDEL R M and DAHL D S Morbidity and mort[illegible] of renal explorat[illegible]

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Fig 7



Fig 8 a



Fig 8 b

Fig 7 Selective angiography, right kidney Cyst 4 cm in diameter located laterally and cranially Another cyst 2 5 cm in diameter located medially Aneurysm in renal artery at division

Fig 8 a) Urography Expanding lesion with calcified wall 6 cm in diameter compressing cranial part of kidney pelvis b) Selective angiography, left kidney Cyst without pathologic vascularity conforming to calcified area Irregular, multilocular cyst in anterior lateral-cranial part of kidney Carcinoma 5 cm in diameter in medial posterior-cranial part of kidney with moderate amount of pathologic vessels

Right kidney (Fig 7) Cyst 5 cm in diameter in lateral part of cranial pole, another cyst 2 5 cm in diameter in medial part of cranial pole At division in dorsal and ventral branches of renal artery, an aneurysm 1 cm in diameter slightly irregular was revealed and considered to be the source of the bleeding

Case 8 Male, aged 64 with prostatic hyperplasia Urography (Fig 8 a) Left kidney slightly enlarged In middle part of kidney a spheric lesion with calcified wall 6 cm in diameter slightly compressing the cranial calices Normal excretion of contrast medium Selective angiography Left kidney (Fig 8 b) Cyst conforming to the calcified lesion Cranial laterally to this cyst a slightly irregular multilocular cyst 5 cm in diameter was found Cranial medially and dorsally, a renal carcinoma 5 cm in diameter close to the cranial part of the calcified process was revealed The tumour was richly supplied by abnormal vessels

Operation confirmed the diagnosis calcified cyst multilocular cyst, and carcinoma in left kidney

General remarks

The cases presented here to exemplify concurrent expanding lesions in the kidneys illustrate several factors of significance in the roentgenologic diagnosis of renal tumour

The detection of an expanding lesion of the kidney, even a large tumour, is occasionally accidental (Olsson 1973) The presence of a mass in one kidney should not distract attention from the other kidney Selective angiography should not be con-

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CATHETERIZATION AND ANGIOGRAPHY OF THE ABDOMINAL ARTERIES IN THE GUINEA-PIG

NIELS EGUND and TORD OLIN

Selective catheterization of the blood vessels of the dog, cat, rabbit and rat, aided by fluoroscopy (RAPPAPORT 1952, LINDELL & OLIN 1957, ADAMS et coll 1965, EKELUND & OLIN 1970), has gained increased importance in experimental investigations No catheterization technique has been described for the guinea-pig although it is a commonly used experimental animal Relatively sparse information about the abdominal vascular anatomy of the guinea pig is available in the literature Therefore, it was thought worthwhile to develop an appropriate technique for selective catheterization and angiography of the abdominal arteries and to describe their anatomy

Material and Methods Sixty two guinea pigs (Cavia porcellus) from four different strains were used, of both sexes and weighing between 300 and 900 g General anaesthesia was obtained by intraperitoneal injection of pentobarbitone sodium in an initial dose of 20 to 30 mg/kg body weight complemented by small supplementary doses The tip of a polyethylene catheter (OPP 10, Portex, England, OD/ID ≈ 0 65/0 25 mm) was tapered to an outer diameter of about 0 3 mm by pulling it in hot air To enable selective catheterization of the abdominal arteries, the tip portion of the

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Table 1

Inner diameter (mm) of the abdominal arteries in 3 individual guinea pigs, and range in 52 guinea pigs

	Guinea pig No			Range (1 52)
	1	2	3	
Aorta cranial to the origin of sup mes a	2 8	3 1	3 4	2 0-3 5
Aorta between sup mes and renal a	2 2	2 7	2 9	1 5-2 9
Aorta caudal to renal a	1 8	2 4	2 5	1 4-2 6
Sup mes. a at origin	2 1	2 4	2 6	1 4-2 6
Sup mes. a. after origin of coel axis	1 9	2.2	2 4	1 3-2 3
Coeliac axis	1 5			1 1 1 9
Gastrosplenic a ,	1 1	1 4	1 5	0 8-1 7
Left gastric a left	0 5	1 1	1 0	0 7-1 4
right	0 6			
Splenic a	0 8	1 1	1 1	0 7-1 4
Common hepatic a	0 8	1 0	1 0	0 6-1 1
Proper hepatic a	0 5	0 7	0 7	0 4-0 7
Gastroduoden a	0 8	0 9	0 9	0 5-1 0
Middle colic a	0 8	1 0	1 2	0 7-1 2
Ileocolic a.	1 0	1 3	1 3	0 8-1 4
Single renal a right		1 8	1 7	1 1-1 8
Single renal a , left		1 9	1 8	1 1-2 1
Dual renal a , right				
upper	1 2			0 8-1 7
lower	0 8			0 6-1 2
Dual renal a., left				
upper	1 3			0 9 1 5
lower	0 8			0 7 1 3
Inf mes a	0 6	0 9	0 9	0 5-0 9
Spermatic a right and left	0 5	0 7	0 7	0 5-0 7

Results

The diameters of the abdominal arteries in 52 guinea-pigs appear in Table 1

The coeliac and mesenteric arteries arose from a common trunk, the coeliaco-mesenteric trunk (Fig 1), in 43 of the 52 guinea-pigs (82%) It arose from the ventral aspect of the abdominal aorta at the level of Th 13 and was the largest branch of the aorta The origin of the branches of the coeliac axis varied (Fig 2) In 21 animals the coeliac axis originated from the common trunk as a single stem, which was very short in 14 animals In 22 animals the coeliac axis was absent and replaced by 2 branches, the gastrosplenic and the common hepatic arteries The coeliac artery (hepatolienogastric trunk) originated from the aorta in 6 animals The gastrosplenic artery originated separately from the aorta in 2 animals (Fig. 4) and the left gastric artery in one animal, whilst the remaining branches of the coeliac axis arose in conjunction with the superior mesenteric artery

catheter was then moulded in hot air or boiling water to a 3 to 4 mm long hook The catheter was stabilized by a thin guide wire of stainless steel and introduced into the femoral artery or into the common carotid artery by a cut-down technique Spasm of the artery was prevented by application of a local anaesthetic without adrenaline After the catheter had been introduced about 1 cm, fluoroscopy was started to avoid perforation

Fourfold magnification fluoroscopy was applied using a tube with a 0 1 mm × 0 1 mm focal spot The distance from the focal spot to the animal was 22 cm and to the image intensifier 90 cm The enlargement could be further increased by using electronic magnification of the image intensifier

Isopaque Cerebral or Isopaque Coronar (metrizoate, Nyegaard, Norway) was employed Films in screen cassettes using direct fourfold magnification or industrial films (Structurix D4 Pb and D7, Agfa-Gevaert) were used Serial angiography was performed using a film changer for 9 cm × 12 cm industrial film (Structurix D4 Pb) immediately beneath the animal, FFD 45 cm (ANGANTYR & OLIN 1973)

Post mortem, about 10 ml of barium sulphate suspension was injected into the common carotid artery The suspension was prepared by dissolving a small amount of gelatin in hot water and mixing with Micropaque (Damancy, England) The animals were placed in a refrigerator for a few hours to allow the gelatin to set in the blood vessels Angiography in various projections and dissection of the specimens were then performed

The coeliac axis, the superior mesenteric artery and the inferior mesenteric artery were investigated in 52 specimens Selective or superselective catheterization of the superior mesenteric artery and its branches was performed in 26 animals, the inferior mesenteric artery was catheterized in 8 animals

The renal circulation was determined in a total of 52 animals The area of the renal arterial supply was examined in vivo by selective and serial angiography in a p as well as lateral projection in 11 guinea-pigs and by stereoscopic angiography of specimens from 18 animals (35 kidneys) The origin of the internal spermatic or ovarian artery was determined in 42 animals The latter artery was frequently catheterized in pregnant guinea-pigs (EGUND & CARTER 1974)

The nomenclature used in human anatomy is followed as closely as possible Constituents of the coeliac axis and superior mesenteric artery are classified in accordance with MICHELS (1955) and LUNDERQUIST (1967) The four lobes of the liver are termed lobus dorsocaudalis dexter and sinister and lobus medius ventralis and dorsalis (NETTELBLAD 1954) The main branches of the renal artery are called the primary, secondary and tertiary branches (HEGEDUS 1972) In the guinea-pig, the tertiary branches are interlobar arteries The thoracic and lumbar vertebrae, which serve as landmarks when locating the origin of the various arteries, are numbered 1 to 13 and 1 to 6, respectively (DEBIESSE 1953)

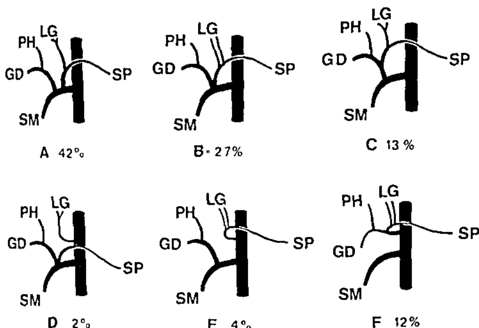
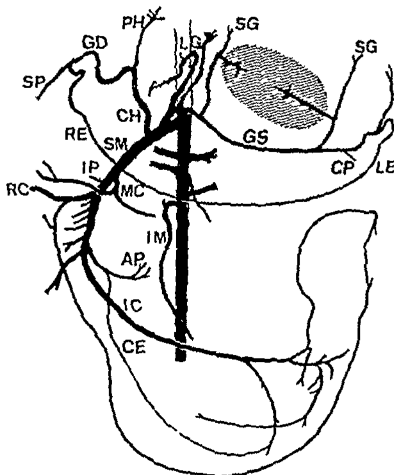


Fig 2. Variations in the origin of the coeliac and superior mesenteric arteries (For abbreviations see Fig 1)

ed with the upper margin of the pancreas It terminated behind the stomach in two main branches the lower short gastric artery and the left gastroepiploic artery The branches of the gastrosplenic artery were the left gastric, short gastric, pancreatic and left gastroepiploic arteries

The left gastric artery (Figs 1, 3) arose from the gastrosplenic artery 3 to 5 mm after its origin In the majority of animals (60%) there was a common stem which divided into 2 branches after 2 to 8 mm In the remaining animals (40%) these branches arose separately from the gastrosplenic artery The left branch supplied the cardio-oesophageal part of the stomach In nearly all animals a small aberrant hepatic artery was given off by one of the cardio oesophageal branches and ran upwards to anastomose within the porta hepatis with the hepatic branch to the lobus dorsocaudalis sinistra or the lobus medius ventralis The right branch descended from the region of the cardia along the lesser curvature of the stomach, sending branches to both its surfaces and terminated in a T-shaped division Anastomosis between the 2 terminal branches is meagre in most instances and is effected by small vessels, which unite with similar branches from the right gastric artery

The short gastric arteries (Figs 1, 3) were invariably two in number and ascended from the gastrosplenic artery to ramify on the dorsal and upper surfaces of the fornix They anastomosed with branches of the left gastric and left gastroepiploic artery



as represent the
in the figures
udal pancreatic
ileal arteries
odenal artery
J = jejunal arteries LE left gastroepiploic artery LG left gastric arteries MC middle colic artery, O = omental artery P pancreatic branches PH proper hepatic artery RC right colic artery RE = right gastroepiploic artery RG right gastric artery SG – short gastric arteries with splenic branches SM – superior mesenteric artery SP superior pancreaticoduodenal artery ST = terminal splenic artery

The distance between the aorta and the origin of the coeliac artery from the coeliacomesenteric trunk (Fig 2 b, c) varied from 6 to 11 mm When the gastrosplenic and common hepatic arteries originated separately (Fig 2 a) the distance from the aorta to the former varied from 4 5 to 7 5 mm and the distance between the origins of the two arteries from 0 1 to 4 5 mm

The gastrosplenic artery (Figs 1, 3) first ran upwards and to the left Then, as it crossed the aorta, it turned obliquely downwards to the left, being intimately associat-

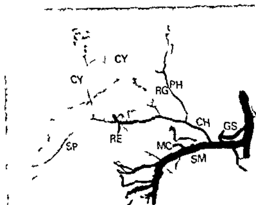


Fig 4 Hepatomesenteric trunk removed after injection of barium sulphate suspension Angiography The gastrosplenic artery originates separately from the aorta The cystic artery originates from the right hepatic artery, which has been cut away The accessory cystic artery originates from the superior pancreaticoduodenal artery (For abbreviations see Fig 1)

hepatic artery The former vessel runs to the right behind the pyloric part of the stomach and then behind the upper part of the duodenum, in which position it divided into two arteries of equal caliber, the superior pancreaticoduodenal artery and the right gastroepiploic artery The head of the pancreas received its arterial supply from small branches arising from the upper part of the superior mesenteric, the common hepatic, the gastroduodenal, and the superior and inferior pancraticoduodenal arteries The latter artery, which is rather small in the guinea-pig, originated from the superior mesenteric artery between the origin of the middle colic artery and the first jejunal artery It anastomosed with the superior pancreaticoduodenal artery along the upper duodenal loop, and one of its branches formed an arcade to the gastroduodenal artery Occasionally, small branches to the pancreas were observed to arise from the middle colic artery

The proper hepatic artery divided into two main branches in the porta hepatis, the right and left hepatic arteries The right hepatic artery seems generally to supply the lobus dorsocaudalis dexter and the larger right hand part of the lobus medius dorsalis The left hepatic artery supplied the lobus dorsocaudalis sinistra and the lobus medius ventralis The cystic artery (Fig 4) originated from the right hepatic artery, but sometimes close to the bifurcation of the proper hepatic artery Another artery to the gall bladder, observed in all but 2 animals, originated from the distal part of the gastroduodenal artery or the upper part of the superior pancreaticoduodenal artery

The filamentous *right gastric artery* most commonly arose from the proper hepatic artery or the left hepatic artery, although sometimes from the gastroduodenal artery and the common hepatic artery Its area of supply was restricted to a small lower part of the lesser curvature and it was surpassed in importance by the much larger left gastric artery and the pyloric branch of the right gastroepiploic artery

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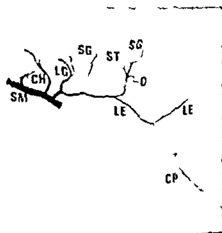


Fig 3 Gastrosplenic arteries removed after injection of barium sulphate suspension Angiography (For abbreviations see Fig 1)

The spleen, situated with its long axis parallel to the lower part of the gastrosplenic artery, generally received its main supply from 2 polar arteries, one of which arose from each of the 2 short gastric arteries In a few animals (ca 10 %) the spleen was supplied by more than 2 arteries, but all arose from the short gastric arteries

The left gastroepiploic artery (Fig 3) reached the stomach at its left border, below the fornix, and descended along and adjacent to the greater curvature, where it invariably directly anastomosed with the right gastroepiploic artery The left gastroepiploic artery gave rise to one or two branches to the fornix, numerous ascending gastric branches to both surfaces of the stomach, pancreatic branches and omental branches

The pancreatic branches of the gastrosplenic artery were numerous, arising throughout its course, and only occasionally was it possible to recognize an arteria pancreatica magna

The caudal pancreatic artery (Fig 3), the largest pancreatic branch, invariably arose between the origin of the gastrosplenic artery and its junction to the greater curvature The caudal pancreatic artery descended within the long tail of the pancreas on the dorsal surface of the stomach and at the end of the pancreas continued to the right in the posterior layer of the great omentum to anastomose with the right gastroepiploic artery A transverse pancreatic artery (originating from the gastroduodenal artery) and arteria pancreatica magna was observed in 2 and 5 animals, respectively, and in all cases anastomosed with the caudal pancreatic artery Small omental branches were given off from the gastroepiploic arteries and the caudal pancreatic artery, forming a coarse network of anastomosing arteries in the great omentum rather than an arcade

The common hepatic artery (Figs 1, 4, 5), ascended 10 to 14 mm towards the porta hepatis before dividing into a larger gastroduodenal artery and a smaller proper

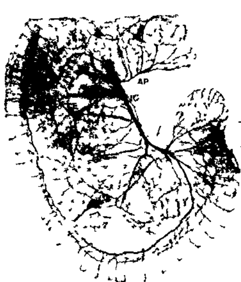


Fig 7

Fig 7 Ileocolic artery removed after injection of barium sulphate suspension Angiography The ileocolic orifice is indicated by the arrow

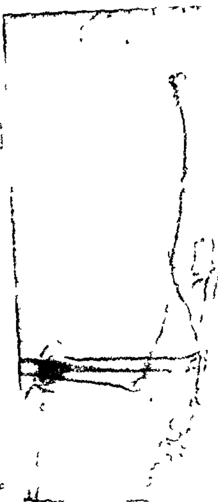


Fig 8

Fig 8 Angiography in vivo Inferior mesenteric artery

the convexity of the arch at the level of the first jejunal arteries The middle colic artery (Fig 6) originated from the superior mesenteric artery between the right colic artery and the coeliac axis and anastomosed with the right and left colic arteries

A large appendicular artery (Fig 7) was given off at the level of the ileocolic artery A caecal branch arising from the appendicular artery or directly from the superior mesenteric artery, ascended along the anterior and posterior taenia coli, to anastomose with lower caecal branches from the ileocolic artery

The inferior mesenteric artery (Fig 8) originated ventrally from the aorta between the middle of L2 and the middle of L3 Within a few mm from its origin, it divided into an ascending left colic artery and a descending branch which terminated in the superior rectal arteries

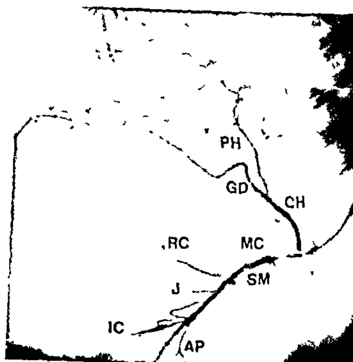


Fig 5 Angiography, in vivo The tip of the catheter in the common hepatic artery (lateral projection) (For abbreviations see Fig 1)



Fig 6 Angiography, in vivo The tip of the catheter in the middle colic artery

off, it crossed to the left side of the abdomen to supply the large coecum and formed an arch, the convexity of which was directed downwards and to the right The last and largest branch, the ileocolic artery, formed a direct anastomosis along the colon with the descending branch of the right colic artery The latter artery originated from

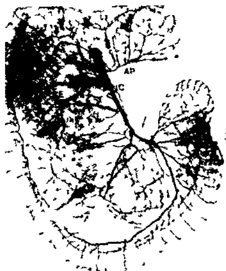
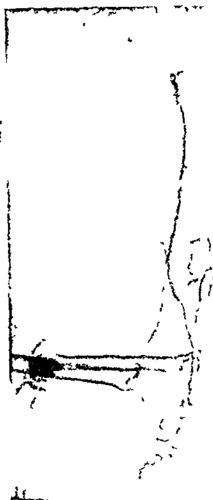


Fig 7

. 7 Ileocolic artery removed after injection of ium sulphate suspension Angiography The colic orifice is indicated by the arrow



g. 8 Angiography in vivo Inferior mesenteric tery

Fig 8

ie convexity of the arch, at the level of the first jejunal arteries The middle colic rtery (Fig 6) originated from the superior mesenteric artery between the right colic rtery and the coeliac axis and anastomosed with the right and left colic arteries
A large appendicular artery (Fig 7) was given off at the level of the ileocolic artery A caecal branch, arising from the appendicular artery or directly from the superior mesenteric artery, ascended along the anterior and posterior taenia coli, to anastomose with lower caecal branches from the ileocolic artery

The inferior mesenteric artery (Fig 8) originated ventrally from the aorta between the middle of L2 and the middle of L3 Within a few mm from its origin, it divided into an ascending left colic artery and a descending branch which terminated in the superior rectal arteries

Table 2

Frequency of multiple renal arteries in 104 kidneys

	No of arteries		
	one	two	three
Right	23	28	1
Left	37	15	
Total	60	43	1

The renal arteries (Fig 9) originated laterally from the aorta between the distal part of Th 13 and the middle of L2 Single renal arteries and the more cranial of dual arteries originated between the distal part of Th 13 and the middle of L1 The right artery arose cranially to the corresponding left artery

Multiple renal arteries were common (Table 2) In the material, only 21 (41 %) had a single renal artery on both sides Fifteen animals had 2 arteries on both the right and the left side, whereas only 2 animals had dual renal arteries on the left and a single artery on the right side Thirteen animals had dual renal arteries bilaterally In one guinea-pig 3 renal arteries were observed on the right side

Variations in the branching of the single renal artery into main or primary arteries were common If the renal artery, between the aorta and the renal pelvis, is divided in three equal segments, the primary branching in 60 kidneys may be said to be early in 5, intermediate in 53 and late in 2 kidneys

An upper polar artery, which never exceeded the size of a secondary branch, was the first renal branch to arise from the renal artery in 80 per cent of the kidneys (Fig 9) This artery originated from the cranial side of the renal artery between the aorta and the primary division (in kidneys with dual arteries or with early division of a single renal artery, the secondary division) Direct origin of the upper polar artery from the aorta was never observed In 16 per cent of the kidneys, all on the left side, the origin of the upper polar artery was early, enabling the tip of the catheter to enter and block it (Figs 9 a, 10)

The distribution of the primary and secondary arteries divided the kidney in one ventral and one dorsal area of supply, strictly demarcated, and contrary to the condition in man (Figs 9, 11) In about half of the kidneys with an upper polar artery, this supplied the greater part of the pole, including both the ventral and the dorsal area (Figs 9, 10) In the remaining half, the supply of the upper polar artery was restricted to the upper hilar margin In kidneys with one artery, the ventral area was typically supplied by the primary ventral artery (Fig 9 a) The dorsal area was supplied by the primary dorsal artery alone in 11 of 17 kidneys In the remaining 6 kidneys a cranial part of the dorsal area was supplied by a secondary branch, arising from the primary ventral artery medial to the pelvis, whilst the caudal part was supplied by the primary dorsal artery (Fig 9 b) Dual renal arteries resemble the two primary branches of a

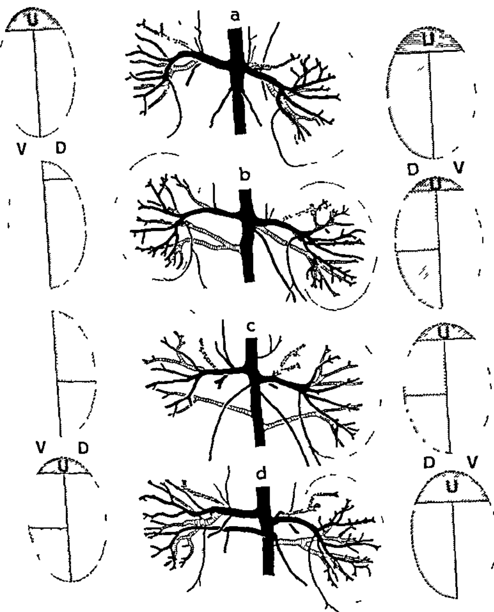


Fig 9 Variations in origin and branching of renal arteries and their areas of supply Ventral arteries black dorsal arteries hatched and upper polar arteries broken lines Areas of supply are indicated schematically in the corresponding lateral projections by D (dorsal) V (ventral) and U (upper polar)



Fig 10 Angiography, in vivo The tip of the catheter in the left upper polar artery Arterial and venous phase

single artery In general, the cranial artery corresponded to the ventral branch and likewise supplied the ventral area and, in about 40 per cent of the cases, a cranial part of the dorsal area (Fig 9 b, c) The caudal artery was generally a dorsal artery although in one kidney it supplied a caudal part of the ventral area (Fig 9 d)

The renal arteries also sent branches to the capsule, the renal pelvis, the ureter, and the suprarenal gland, and a well developed muscular branch existed (Fig 12) The latter, up to 0 7 mm in width, originated from the dorsal side of a single renal artery or the more cranial of dual renal arteries It originated often near the aorta and consequently may unintentionally be entered during catheterization of the renal artery (Fig 12) At its origin or later it divided into 3 branches The ascending branch, the subcostal artery, often gave rise to or anastomosed with the twelfth intercostal artery The descending branch anastomosed with the ileolumbar artery The inferior capsular artery, which arose from the distal branch of the ventral renal artery, sent branches to the cranial part of the ureter The superior capsular artery originated from the single renal artery, or the more cranial of dual renal arteries In the female guinea-pig, a capsular branch was observed to emanate from the ovarian artery (Fig 13) The suprarenal gland was supplied by small arteries originating from the muscular artery, the inferior phrenic artery, and by branches of the renal artery and the upper polar artery In a few cases suprarenal arteries arose from the aorta

The origin of the *inferior phrenic arteries* was often difficult to define They most commonly arose from the first part of the coeliacomesenteric trunk but even from the renal arteries (Fig 12) and the aorta



Fig 11 a



Fig 11 b

Fig. 11 Angiography in vivo Left kidney with dual arteries a) Selective injection of contrast medium into the cranial artery a p projection b) the caudal artery true lateral projection The areas of supply correspond to those in Fig 9 c

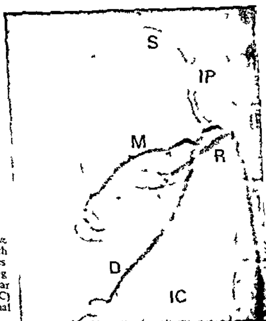


Fig 12

Fig 12 Angiography in vivo The tip of the catheter was placed in the muscular branch arising from the more cranial of dual arteries IP inferior phrenic artery S ascending M middle and D descending muscular branches The inferior capsular artery (IC) originates from a ventral branch of the renal artery (R)

Fig 13



Fig 14

Fig 14 Angiography, in vivo, of the [illegible] animal The ovarian artery (Oa) origi[illegible] o the ovary (Ov), large spiral artery [illegible] Contrast medium appears in the corresponding vein

[illegible] *arteries or ovarian arteries* (Fig 14) originated from the [illegible] close relation [illegible] found to to them In 10 per cent of female [illegible] originate from the more caudal of dual renal arteries (Fig 13)

The larger branches of the abdominal aorta, i e the coeliacomesenteric trunk and the single renal arteries, were easily catheterized with a hooked catheter introduced from a femoral or common carotid artery Arteries of smaller width, such as dual renal arteries, internal spermatic, ovarian, inferior mesenteric and lumbar arteries, were seldom difficult to catheterize but due to their small width they were easily occluded. Occlusion could cause spasm or irreversible injury, especially in the kid-

neys Injection of contrast medium into the lumbar arteries often resulted in convulsions In pregnant animals, the ovarian artery was easily catheterized as was the uterine artery, originating from the internal iliac artery (EGUND & CARTER 1974)

It was often possible to catheterize the main branches of the coeliacomesenteric trunk, including the superior mesenteric artery, from the carotid artery The hooked catheter used for this purpose was gently bent, in the same direction as the hook, about 10 to 12 mm from its tip and the guidewire was similarly shaped (Fig 6) Even the middle colic artery could be catheterized in this way

Discussion

The anatomy of the abdominal arteries in the guinea-pig has been described by RATKE (cited by BROMAN 1906), LUTHER (1923), POTTER et coll (1958), FAVRE (1967), and PERNECZKY (1969), more specific investigations are reported by SCHABADASCH (1935) on the splenic artery, PAVAUX & PUGET (1972) on the ileocolic artery, EGUND & CARTER (1974) on the uterine and placental circulation, and KNOX-MACAULAY et coll (1960) on the arterial supply to the spinal cord

The coeliacomesenteric trunk is considered to exist invariably (RATKE, LUTHER, POTTER et coll, FAVRE) POTTER et coll and FAVRE state that a coeliac artery originates from the coeliacomesenteric trunk, whereas LUTHER maintains a constant, separate origin for the gastrosplenic and common hepatic arteries LUTHER & FAVRE agree that dual renal arteries are usual whereas POTTER et coll describe only single renal arteries The number of animals on which these conflicting opinions are based seems uncertain

PERNECZKY (1969) observed the coeliac artery to arise from the aorta in one animal in a material of 30 guinea-pigs He found a separate origin for the gastrosplenic and common hepatic arteries in 16 animals (54 %) and a common stem for these arteries in 13 animals (42 8 %) These figures are in relatively good agreement with the frequencies observed in the present material

The frequent occurrence of a coeliacomesenteric trunk in the guinea pig distinguishes it from other laboratory animals, such as the rat (GREENE 1955), and the rabbit (KRAUSE 1884) A coeliacomesenteric trunk has repeatedly been reported to occur in man (ADACHI 1928, LIPSHUTZ 1917, MICHELS 1955) and is normal in the mole (Talpa europaea TANDLER 1904 b) as it is in the frog and many lower vertebrates (SCHABADASCH 1935) The formation of a coeliacomesenteric trunk and the variation in origin of the coeliac branches has been explained by TANDLER (1904 a, b) In early human and Talpa europaea embryos the omphalomesenteric artery arises from the aorta by four roots, which are united by a ventral longitudinal anastomosis If the anastomosis, from which the three main branches of the coeliac artery originates persists and the three most cranial roots atrophy a coeliacomesenteric trunk is formed

Multiple renal arteries are frequently found in man (BOIJSEN 1959), as well as in

the dog (MILLER et coll 1964, REIS & TEPE 1956) and cat (RIECK & REIS 1953), but occur much more frequently in the guinea-pig In an analysis of 60 kidneys, PERNECZKY (1969) found that 27 per cent had dual renal arteries, as compared to 41 per cent in the present material He also found a larger number of dual renal arteries on the left side than on the right whereas the opposite pertains in the present material These differences in frequency may be ascribed to the relatively small size of the two series The branching and distribution of the renal artery of the guinea-pig have not previously been described Contrary to conditions in other laboratory animals, in 35 per cent of guinea-pigs the primary ventral branch of the single renal artery also supplies parts of the dorsal area The single renal artery of the dog invariably divides into one primary anterior and one primary posterior branch with a typical ventro dorsal distribution (KLAPPROTH 1959) The arterial distribution in the rat and the rabbit is principally the same as in the dog (FOURMAN & MOFFAT 1971)

The catheterization technique developed during this investigation should prove valuable in analyzing pharmacodynamic responses to various drugs when administered atraumatically in the artery supplying an organ It also offers an opportunity to follow pathologic processes, such as tumour growth by angiography on different occasions (EKELUND et coll 1974)

SUMMARY

The abdominal arterial anatomy of the guinea-pig was investigated by angiography and dissection Normally, a coeliacomesenteric trunk was found, although various forms transitional to the hepatolienogastric trunk were found Multiple renal arteries were common in comparison to other laboratory animals and to man A technique for selective catheterization of the abdominal arteries is described

ZUSAMMENFASSUNG

Die abdominale arterielle Anatomie des Meerschweinschens wurde durch Angiographie und Dissektion untersucht Meistens wird ein coeliaco mesenterialer Stamm gefunden, obwohl verschiedene Formen mit Übergang zu einem hepato lieno gastrischen Stamm gefunden wurden Multiple renale Arterien waren im Vergleich zu anderen Laboratoriumstieren und zum Menschen gewohnlich Die Technik der selektiven Katheterisierung der abdominalen Arterien wird beschrieben

RESUMÉ

L'anatomie des artères abdominales du cobaye a été étudiée par angiographie et par dissection Normalement on trouve un tronc coeliaco-mésentérique, bien qu on trouve diverses formes de transition vers un tronc hépato spléno gastrique Les artères rénales multiples sont fréquentes par rapport aux autres animaux de laboratoire et à l homme Description d'une technique de cathétérisme sélectif des artères abdominales

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HYDRO- AND HEMODYNAMIC EFFECTS OF CATHETERIZATION OF VESSELS

I. An experimental model

L. BJORNO and H. PETTERSSON

Catheterization of arteries and veins is fundamental to angiography, to volumetric flow rate measurements with, for instance, dye dilution technique and to intravascular pressure readings. When a catheter is introduced into a vessel, it may disturb the possible hemodynamic steady state that existed before the catheterization. However, very few reports concerning the hemodynamic consequences of catheterization have appeared and thus these effects are still incompletely known (BERÁNEK & DOSKOCIL 1968, BERANEK 1971, CROWE & KROVETZ 1970).

Model experiments are suitable for analysis of the effects of catheterization. The parameters which should be possible to record under controlled conditions by means of the model are: (1) static and dynamic pressure, (2) volumetric flow rate, (3) type of flow (i.e. steady or pulsatile flow), (4) repetition frequency, shape and amplitude of pressure surges in pulsatile flow, (5) peripheral resistance of the vessels, (6) diameter and length of the vessels and of a possible stenosis, (7) the elastic properties of the vessel walls, and (8) the composition and the viscosity of the fluid used. An experimental model fulfilling these demands has been constructed.

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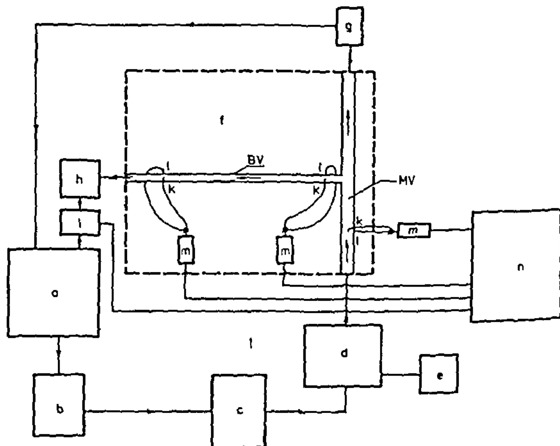


Fig. 1 Block diagram of the experimental set-up a—Fluid reservoir b—Centrifugal pump c—Temperature stabilizer d—Pressure control equipment e—Vario transformer f—Interchangeable section including (M V) main vessel and (B V) branch vessel g—Peripheral resistance bed h—Variable resistance device i—Flowmeter k—Hypodermic needles for stagnation pressure measurements l—Hypodermic needles for static pressure measurements m—Pressure transducer n—Paper tape recorder → Direction of the fluid flow

The model consists of three *main parts* (A) An apparatus producing controllable flow and pressure variations, (B) a model of the vessels to be catheterized and (C) a recording device for pressure and volumetric flow rate A block diagram of the experimental set-up is given in Fig 1, and photos in Figs 2 and 3 The letters in parenthesis, given in the following text, refer to these figures

A *Apparatus for generation of controllable flow and pressure conditions* From a reservoir (a in Figs 1, 2) the fluid is sucked to a centrifugal pump (b), which it leaves under a static pressure of $5 \cdot 10^5$ Pa Having passed a temperature stabilizer (c) for temperature control, the fluid pressure is varied by means of a reduction valve, EB D ZON (Jacobi) (α in Fig 3) The pressure reduction in the valve is controlled by a spring-loaded membrane When the spring load is kept constant, the static pressure of the fluid leaving the valve is constant The spring load, and thus the static mean pressure of the fluid flow, is controlled by adjusting a circular disc

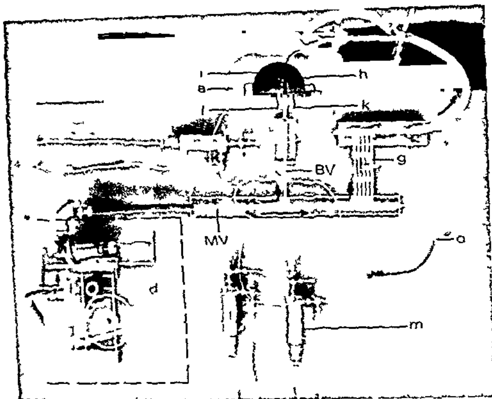
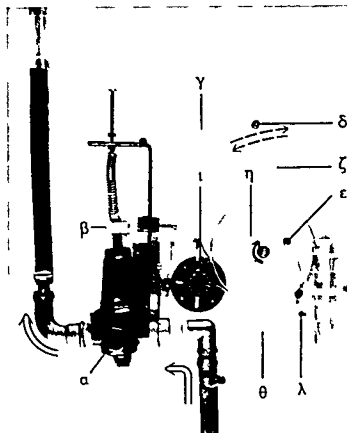


Fig. 2 Example of an exper men [illegible] essure control
equ pment (cf F g 3) [illegible] ible resistance
device in the branch ves [illegible] odermic needle
for stagnation *pressure* [illegible] m—Pressure
transducer o—Catheter [illegible] Branch vessel
→ D rect on of flu d flow

having a notch for a driving wire arrangement (β) The wire (γ) is connected through a lever (δ–ε) for pressure amplitude adjustment to a cam disc (η) producing periodic variations in the wire tension and through it in the spring load The rotation of the cam disc is produced by an electric motor, by means of which the number of revolu tions of the cam disc is controlled through a vario transformer (e) The cam disc rotation produces a synchronous periodical pressure time variation—a pulse—in the fluid flow through the reduction valve with the pulse shape being determined by the shape of the cam disc

The pressure amplitude just distal to the reduction valve may be varied between 5 3 10^3 and 4 0 10^4 Pa (i e 40 to 300 mm Hg 1 mm Hg 133 3 Pa) and the volu metric flow rate may be varied between 0 and 5 000 ml/min The entire accuracy in the experimental determination of the volumetric flow rate and the pressure is about 2 per cent (see section C) The temperature is controlled by the stabilizer with an accuracy of ±0 5 C within the temperature range of 30 to 40 C



... Red ... on val e β—Circular d sc con ... ssure of the flu d ... of the lever arm ... η) ... —Lever arm ... rm (δ) and to the disc (β) and used as a remote control of the static mean pressure ι Electrical motor and var o transformer (below the table) producing rotation of the cam disc λ—Center of the lever arm movement —›Direction of fluid flow —›Rotational d rect on of the cam disc ›D rections of the lever arm movements The shape of the cam dis determ nes the shape of the pulse wave The length of the adjustable lever arm (the distance between δ and ϵ) determ nes the pulse ampl tude The rotat on speed of the cam disc determ nes the pulse frequency

B *Vessel model* The model described here is only one out of a number of different interchangeable versions

The fluid flow after the reduction valve mentioned in section A enters a main vessel (M V) which is connected to a branch vessel (B V) (Figs 1 2) forming a right angle with the main vessel The vessels are built of perspex or latex The perspex may be considered as rigid for the flow conditions while the latex is elastic The inner diameter of the main vessel is 10 0 mm The inner diameter of the branch vessel may be varied but is always kept smaller than the diameter of the main vessel

Connected to the distal end of the main vessel is a peripheral resistance bed (g) a throttling device consisting of a number of soft plastic tubes with an internal diameter of 2 to 3 mm which is controlled and may be reduced by means of clamping

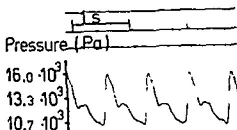


Fig 4 Shape of the pressure pulse wave

screws in order to increase the peripheral resistance The fluid passing through the peripheral resistance returns directly to the fluid reservoir (a)

Also at the outlet from the branch vessel a variable resistance device (h) is mounted This device consists of a set of interchangeable, rigid plastic tubes, all having the same internal diameter as the branch vessel These tubes are closed at one end, and the outflow from the tubes occurs through a hole with a diameter different from tube to tube, thus making it possible to adjust a resistance suitable for the specific flow conditions considered in the branch vessel The fluid flow leaving the side hole of a resistance tube is measured by means of an accurate flowmeter (i) (see section C) Having passed this flowmeter, the fluid returns to the reservoir (a)

The main vessel and the branch vessel may be taken apart, thus making it possible to change the diameter of the vessel considered Further, the main and branch vessels consist of tube sections, tightly fixed to each other, making it possible to catheterize and to interpose a preformed stenosis

C *Recording device for pressure and volume flow* For measurement of the stagnation pressure, thin hypodermic needles of the Pitot type are introduced into the vessels at appropriate sites (k) The external and the internal diameters of the needles are 0 8 mm and 0 4 mm, respectively, and their length is 30 mm The needles have a right angle bending 2 mm from the tip, leaving the 2 mm of the needle length axially positioned in the vessel, parallel to the vessel wall, and with the needle opening towards the direction of the stream The static (lateral) pressure is measured by means of straight hypodermic needles of the same diameters as the needles for the stagnation pressure measurements, with their open ends flush-mounted with the inner tube walls (l)

The difference between the stagnation pressure measured at a tube position and the static pressure measured at the same position yields the dynamic pressure, originating from the local particle velocity of the fluid flow

Through 300 mm long polyethylene catheters with an internal diameter of 1 6 mm, the hypodermic needles are connected to pressure transducers (m), EMT 34 0 to 300 mm Hg (Siemens-Elema), giving a pressure determination with an accuracy of approximately ±2 per cent of full scale display

The volumetric flow rate measurements are performed by means of a flowmeter

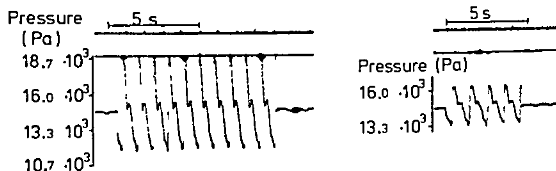


Fig 5 The pulse amplitude is varied, while the mean pressure level is kept constant

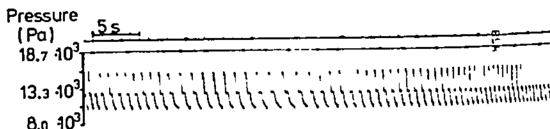


Fig 6 The frequency is varied, while the amplitude and the mean pressure level are kept constant

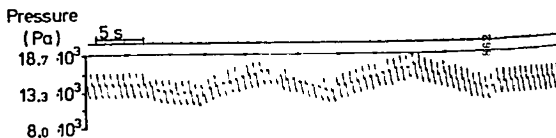


Fig 7 The mean pressure level is varied, while the frequency and the pulse amplitude are kept constant

(i), EMT 434 (Siemens-Elema) A modification of the flowmeter has been introduced in order to make possible a recording of steady or pulsatile volumetric flow rate Through different introduced sensitivity ranges of the flowmeter the volumetric flow rate can be determined between 40 and 1 500 ml/min with an accuracy of ±2 per cent of full scale display

The pressure transducer and the flowmeter are both connected to a recording instrument (n), Mingograf 800 (Siemens-Elema), for continuous recording of the events on paper tape

Examples of pressure-time variations, produced by the apparatus and recorded in the vessel model The shape of the pulse pressure-time course is determined by the shape of the cam disc The recorded pressure-time curve of the pulses produced by the equipment described in section A appears in Fig 4 The pressure-time curve should

simulate the pressure variation with time measured in the distal aorta of a young healthy man Figs 5 and 6 illustrate that the pulse amplitude and the frequency, respectively, can be varied without disturbing the mean pressure level The mean pressure level may be varied, with the amplitude and frequency being kept constant (Fig 7) All recordings in Figs 4 to 7 are measured by means of the hypodermic needle of the Pitot type positioned in the main vessel

Discussion

The equipment constituting a mechanical model for experimental flow investigations during catheterization makes it possible under controlled conditions to determine the static and the dynamic pressure together with the volumetric flow rate as a function of (1) the type of the flow, (2) the repetition rate, the amplitude and the shape of pulses, (3) the peripheral resistance, (4) the geometry and the dimensions of a stenosis or catheter piece, (5) the physical properties of the vessel walls and (6) the physical properties of the fluid used in the experiments

The pressure amplitude obtained by means of the equipment may be varied between 5 3 10^3 and 4 0 10^4 Pa (i e , the region of arterial pressure) For recordings of lower pressures at steady flow, an experimental model like the one described by BERÁNEK & DOSKOCIL (1968) may be appropriate

An advantage of the present experimental model is the fact that the vessel wall material may be varied enabling an analysis of the influence of the wall elasticity upon the flow conditions in the vessels Rigid perspex walls yield an easier and more exact determination of the vessel diameters, and further, it makes possible both optical and radiologic examinations of the flow during catheterization

The influence of elastic vessel walls especially on the shape and the amplitude of pressure pulses but also on the steady flow, may easily be determined by means of the model

By the use of fluids of different viscosities the influence of viscosity on the pressure and the volume flow through the vessels can be investigated Unfortunately, however, normal blood cannot be used due to mechanical hemolysis by the passage through the reduction valve The strong pressure gradient across the reduction valve is necessary however if a constant static pressure in the fluid at the outlet from the valve is desired Instead of normal blood, plasma substitutes may advantageously be used

This mechanical model has been used to investigate the hydrodynamic effects of catheterization and results will be reported subsequently

SUMMARY

A mechanical model for experiments on the influence on pressure and volumetric flow rate arising from catheterization is described It is possible under controlled conditions to determine the static and dynamic pressure together with the volumetric flow rate as a

function of flow type, repetition frequency, shape and amplitude of pressure surges in pulsatile flow, peripheral resistance, geometry and dimensions of a stenosis or a catheter, and physical properties of the vessel wall materials and of the fluid employed

ZUSAMMENFASSUNG

Ein mechanisches Modell für Experimente über den Einfluss auf Druck und volumetrische Durchströmung, die während Katheterisierung auftreten, wird beschrieben Es ist möglich, unter kontrollierten Verhältnissen, den statischen und dynamischen Druck zusammen mit der volumetrischen Durchströmung als eine Funktion der Durchströmungsart Wiederholungsfrequenz, Form und Amplitude der Druckwellen bei pulsierendem Fluss, peripherer Widerstand, Geometrie und Dimensionen einer Stenose oder eines Katheters und physikalische Eigenschaften des Gefässwandmaterials und der verwendeten Flüssigkeit zu bestimmen

RÉSUMÉ

Description d'un modèle mécanique destiné à une expérimentation sur l'influence du cathétérisme sur la pression et le débit volumetrique Il est possible, dans des conditions contrôlées, de déterminer la pression statique et dynamique en même temps que le débit volumétrique en fonction du type de débit, de la fréquence de répétition, de la forme et de l'amplitude des à-coups de pression en débit pulsatile, de la résistance périphérique, de la géométrie et des dimensions d'une sténose ou d'un cathéter et des propriétés physiques des constituants de la paroi vasculaire et du fluide employé

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CROWE W J and KROVETZ L J Analysis of three-dimensional flow birefringence models, with a note on the effects of catheters and needles on vessel flow IEEE Trans Biomed Eng 17 (1970), 199

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KINEMATIC ANALYSIS OF POSTEROLATERAL FUSION IN THE LUMBOSACRAL SPINE

T H OLSSON, G SELVIK and S WILLNER

In the past much effort has been devoted to the subject of spinal fusion and a great number of authors have reported various degrees of success (ROLANDER 1966) The various surgical techniques may partly explain the wide range of results, but the uncertainty of the methods previously used in determining the degree of spinal fusion obtained may also be a factor This opinion is supported by ADKINS (1955) who states estimation of fusion by mobility radiographs is unreliable and cannot distinguish between fibrous ankylosis and bony fusion'

In experimental animals, the present authors (1975 a) showed that all movements between segments that have not fused with a complete bony union on both sides may be detected and quantified by a roentgen stereophotogrammetric method (SELVIK 1974) Therefore the stability in the lumbosacral spine after posterolateral fusion was tested in three patients using this method

Case reports

Case 1 Woman 46 years old with low back pain for 20 years and with spondylolysis of L5 with spondylolisthesis between L5 and S1 (grade 1 according to MEYERDING 1932)

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function of flow type, repetition frequency, shape and amplitude of pressure surges in pulsatile flow, peripheral resistance, geometry and dimensions of a stenosis or a catheter, and physical properties of the vessel wall materials and of the fluid employed

ZUSAMMENFASSUNG

Ein mechanisches Modell fur Experimente über den Einfluss auf Druck und volumetrische Durchstromung, die wahrend Katheterisierung auftreten, wird beschrieben Es ist moglich, unter kontrollierten Verhaltnissen, den statischen und dynamischen Druck zusammen mit der volumetrischen Durchstromung als eine Funktion der Durchstromungsart, Wiederholungsfrequenz, Form und Amplitude der Druckwellen bei pulsierendem Fluss peripherer Widerstand, Geometrie und Dimensionen einer Stenose oder eines Katheters und physikalische Eigenschaften des Gefasswandmaterials und der verwerdeten Flussigkeit zu bestimmen

RÉSUMÉ

Description d'un modèle mécanique destine à une expérimentation sur l influence du cathétérisme sur la pression et le debit volumétrique Il est possible, dans des conditions contrôlees, de déterminer la pression statique et dynamique en meme temps que le débit volumétrique en fonction du type de débit, de la fréquence de répetition, de la forme et de l'amplitude des à-coups de pression en débit pulsatile, de la résistance périphenque, de la géométrie et des dimensions d'une sténose ou d'un catheter et des proprietes physiques des constituants de la paroi vasculaire et du fluide employé

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CROWE W J and KROVETZ L J Analysis of three dimensional flow birefringence models with a note on the effects of catheters and needles on vessel flow IEEE Trans Biomed Eng 17 (1970), 199

Table 1

The mean errors of rigid body fitting for each vertebra at the third examination of the three patients and the contribution of measurement errors to these mean errors

Case		Lateral bending left right	Extension flexion	Axial rotation left–right	Measurement errors Mean value ± SE
1	L3	69*	22	61	39 ± 23
	L4	54	13	74	40 ± 21
	L5	37	25	38	37 ± 22
	S1	27	52	65	33 ± 20
2	L4	47	72	41	28 ± 22
	L5	47	44	32	17 + 11
	S1	38	21	10	16 ± 9
3	L2	45	52	137	40 ± 23
	L3	30	43	160	27 ± 13
	L4	86	94	11	36 ± 15
	L5	11	83	60	30 ± 15
	S1	21	80	38	47 + 12

* Unit μm

Methods

During the operations tantalum spherical indicators (0 8 mm in diameter) were inserted into the neural arches of the vertebrae operated upon by the technique described by ARONSON et coll (1974) Such indicators were also inserted into L3 in Case 1 and L2 in Case 3, serving as control segments Each vertebra with lysis in the arches was regarded as two segments, both of which were indicated The motions of the posterior segments of these vertebrae were, however, left out of consideration, the chief object in these cases being to ascertain whether or not the spondylolisthesis in question had been stabilized The examination procedure was the same as described previously (OLSSON et coll 1976 b), i e one film was exposed by two roentgen tubes simultaneously and horizontal beam direction A calibration cage, which was exposed before the exposure of the patient on each film, was placed so that its x-axis approximated a transversal axis of the patient, the y-axis a longitudinal, and the z-axis a sagittal axis (Fig 1) All patients were examined on three occasions in a standing position both erect and during maximal lateral bendings, flexion, extension and axial rotations Case 1 was examined 111, 174 and 275 days postoperatively, Case 2 109, 174, and 357 days postoperatively, and Case 3 116, 182, and 285 days postoperatively

The Eulerian rotations and the translations about and along the three coordinate axes were computed for each vertebra in relation to its subjacent segment In addition the total rotation and translation for the segments in question were calculated The center of gravity for the indicators within each vertebra was chosen as the base-point for the translations To describe the development of the movements achieved

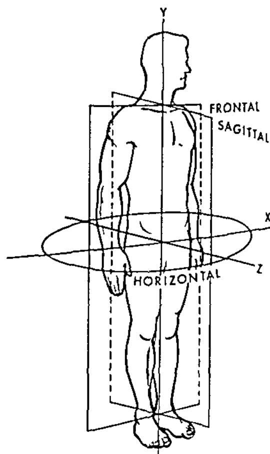


Fig 1 The coordinate axes to which the [illegible] human motion Saunders Philadelphia 1962)

Conservative treatment was not successful Posterolateral fusion from L4 to S1 was performed with decortication of the vertebral arches and transversal processes, destruction of the intervertebral joints and autotransplantation of bonechips from the iliac crest The patient was kept in a plaster bed the first 60 days after operation and then mobilized with a brace (hyperextension orthosis, Camp Co, Jackson, Michigan, USA) There were no complications At examination 275 days after operation the patient was still suffering from a stiff, painful back with muscle contractions

Case 2 Woman, 22 years old who during pregnancy three years previously developed low back pain A spondylolysis of L5 with olisthesis between L5 and S1 (grade 1) was found No improvement was gained by conservative treatment A posterolateral fusion was therefore performed between L4 and S1 The operation technique was the same as in Case 1 Postoperatively the patient was uneventfully treated in a plaster bed for 60 days and then mobilized with a brace One year after the operation the patient was relieved of pain except during extreme movements

Case 3 Labourer, 56 years of age, who had suffered from low back pain and sciatica for 20 years The fourth lumbar disk was degenerated, and as conservative treatment was without effect, a posterolateral fusion from L3 to S1 was made The operation was performed with decortication, destruction of intervertebral joints, and bone transplantation in the same way as in the first two patients The postoperative treatment was also the same, with recumbency in a plaster bed for 60 days and subsequent mobilization with a brace At examination 285 days postoperatively the patient had no pain but had a feeling of weakness in his back

Table 1

The mean errors of rigid body fitting for each vertebra at the third examination of the three patients and the contribution of measurement errors to these mean errors

Case		Lateral bending left-right	Extension-flexion	Axial rotation left-right	Measurement errors Mean value ± SE
1	L3	69*	22	61	39 ± 23
	L4	54	13	74	40 + 21
	L5	37	25	38	37 ± 22
	S1	27	52	65	33 ± 20
2	L4	47	72	41	28 + 22
	L5	47	44	32	17 ± 11
	S1	38	21	10	16 ± 9
3	L2	45	52	137	40 ± 23
	L3	30	43	160	27 ± 13
	L4	86	94	11	36 ± 15
	L5	11	83	60	30 ± 15
	S1	21	80	38	47 ± 12

* Unit μm

Methods

During the operations tantalum spherical indicators (0 8 mm in diameter) were inserted into the neural arches of the vertebrae operated upon by the technique described by ARONSON et coll (1974) Such indicators were also inserted into L3 in Case 1 and L2 in Case 3, serving as control segments Each vertebra with lysis in the arches was regarded as two segments, both of which were indicated The motions of the posterior segments of these vertebrae were, however, left out of consideration, the chief object in these cases being to ascertain whether or not the spondylolisthesis in question had been stabilized The examination procedure was the same as described previously (OLSSON et coll 1976 b), i e one film was exposed by two roentgen tubes simultaneously and horizontal beam direction A calibration cage, which was exposed before the exposure of the patient on each film, was placed so that its x-axis approximated a transversal axis of the patient, the y-axis a longitudinal, and the z-axis a sagittal axis (Fig 1) All patients were examined on three occasions in a standing position both erect and during maximal lateral bendings, flexion, extension and axial rotations Case 1
and 357 days [illegible] 74,

The Euleria [illegible] and the translations about and along the three coordinate axes were computed for each vertebra in relation to its subjacent segment In addition, the total rotation and translation for the segments in question were calculated The center of gravity for the indicators within each vertebra was chosen as the basepoint for the translations To describe the development of the movements achieved

Table 2

The standard errors s_ϕ, s_ψ, and s_θ, for the Eulerian rotations and s_x, s_y, and s_z for the translations as well as the standard errors s_{rot} and s_{tr} for the total rotations and translations for the various segment pairs of the three patients

Case		s_ϕ	s_ψ	s_θ	s_{rot}	s_x	s_y	s_z	s_{tr}
1	L3-L4	0.09*	0.12	0.07	0.16	25**	15	34	44
	L4-L5	0.23	0.18	0.06	0.30	16	31	103	110
	L5-S1	0.30	0.25	0.07	0.40	184	202	204	363
2	L4-L5	0.21	0.05	0.05	0.22	25	61	85	107
	L5-S1	0.37	0.17	0.05	0.41	123	134	171	250
3	L3-L4 + L5-S1	0.12	0.13	0.07	0.19	26	23	58	83

* Unit degrees
** Unit μm

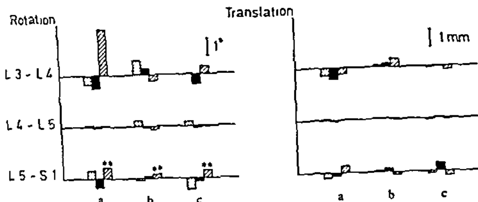
Table 3

Case 1. The total rotations and translations between the pairs of vertebrae in the three examinations

Segment pair	Days after operation	Lateral bending left–right		Extension flexion		Axial rotation left right	
		Rot	Transl	Rot	Transl	Rot	Transl
L3-L4	111	4.3*	4.26**	0.9	0.52	0.3	0.17
	174	2.3	0.64	1.7	0.66	1.1	0.23
	275	2.9	0.88	1.0	0.55	0.8	0.25
L4-L5	111	3.7	0.88	0.2	0.06	0.8	0.11
	174	0.5	0.12	0.7	0.15	0.4	0.04
	275	0.1	0.08	0.4	0.09	0.3	0.06
L5-S1	111	4.2	3.71	0.5	0.65	1.0	0.57
	174	0.7	0.27	0.6	0.42	0.8	0.27
	275	1.0	0.52	0.3	0.28	0.8	0.59

* Unit degrees
** Unit mm

during the three successive examinations of the patients the total rotations and translations were chosen for the following movements: lateral bending from left to right, flexion from extended to flexed position, and axial rotation from left to right. In order to obtain a more detailed analysis of the motions between the vertebrae at the third examination of each patient, the Eulerian rotations and the translations relative to the three axes in space were also reported. A test of the precision of the method



[illegible] staple group represents a particular movement) For segments L4–L5 and L5–S1, operated upon, the values significantly ($p < 0.01$) different from zero, including two highly significant ($p < 0.001$) values are marked (**) Level considered diseased L5–S1 a = Lateral bending left–right, b = Extension flexion c = Axial rotation left–right

was performed by re-evaluation of seven films from the third examination of each patient The contribution of the measurement errors to the mean error of rigid-body fitting (SELVIK 1974, p 117) was also computed from this test

Results

The mean errors of rigid-body fitting for the different segments in the three patients at the third examination are given in Table 1 These errors range between 10 and 160 μm The contribution of the measurement errors to the total mean error of [illegible]

[illegible] between 10 and 47 μm, and the standard error for each determination is about 20 μm

The standard errors s_ϕ, s_ψ, and s_θ for the rotations and s_x, s_y, and s_z for the translations about and along the x-, y-, and z-axes, which were computed from the precision test, appear in Table 2 The standard errors s_{rot} and s_{tr} for the total rotations and translations are also given Assuming a Gaussian distribution of these errors, the significant motions can be calculated (7 d f for Cases 1 and 2, 14 d f for Case 3) using the Student's t-test

Case 1 The examinations of this patient who was operated on L4–S1 because of spondylolisthesis L5–S1 are accounted for in Table 3 During the first examination, which was performed 111 days postoperatively, the total rotation for L5–S1 was

Table 2

The standard errors s_ϕ, s_ψ, and s_θ, for the Eulerian rotations and s_x, s_y, and s_z for the translations as well as the standard errors s_{rot} and s_{tr} for the total rotations and translations for the various segment pairs of the three patients

Case		s_ϕ	s_ψ	s_θ	s_{rot}	s_x	s_y	s_z	s_{tr}
1	L3-L4	0.09*	0.12	0.07	0.16	25**	15	34	44
	L4-L5	0.23	0.18	0.06	0.30	16	31	103	110
	L5-S1	0.30	0.25	0.07	0.40	184	202	204	363
2	L4-L5	0.21	0.05	0.05	0.22	25	61	85	107
	L5-S1	0.37	0.17	0.05	0.41	123	134	171	250
3	L3-L4 + L5-S1	0.12	0.13	0.07	0.19	26	23	58	83

* Unit degrees
** Unit μm

Table 3

Case 1 The total rotations and translations between the pairs of vertebrae in the three examinations

Segment pair	Days after operation	Lateral bending left–right		Extension flexion		Axial rotation left–right	
		Rot	Transl	Rot	Transl	Rot	Transl
L3–L4	111	4.3*	4.26**	0.9	0.52	0.3	0.17
	174	2.3	0.64	1.7	0.66	1.1	0.23
	275	2.9	0.88	1.0	0.55	0.8	0.23
L4–L5	111	3.7	0.88	0.2	0.06	0.8	0.11
	174	0.5	0.12	0.7	0.15	0.4	0.04
	275	0.1	0.08	0.4	0.09	0.3	0.06
L5–S1	111	4.2	3.71	0.5	0.65	1.0	0.57
	174	0.7	0.27	0.6	0.42	0.8	0.27
	275	1.0	0.52	0.3	0.28	0.8	0.59

* Unit degrees
** Unit mm

during the three successive examinations of the patients the total rotations and translations were chosen for the following movements lateral bending from left to right, flexion from extended to flexed position, and axial rotation from left to right In order to obtain a more detailed analysis of the motions between the vertebrae at the third examination of each patient, the Eulerian rotations and the translations relative to the three axes in space were also reported A test of the precision of the method

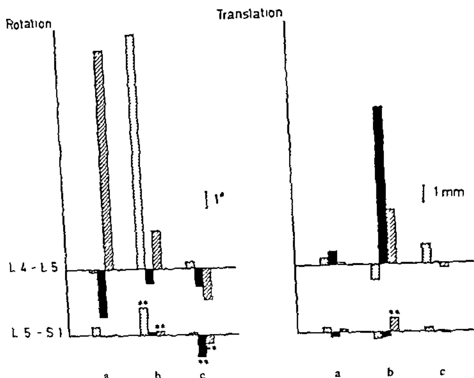


Fig 3 Case 2 357 days after operation The Eulerian rotations and the tran

significant rotation 1 9° and two significant translations both equal to 1 03 mm between L5–S1 during extension-flexion, lateral bendings, and axial rotation, respectively For L4–L5 the rotation 7 9° and the translation 5 85 mm were encountered during extension flexion At the third examination 357 days after operation the significant rotations 1 8° and 1 4° were found between L5–S1 for extension-flexion and axial rotation, respectively During the same extension-flexion the translation was 0 97 mm The rotations for the third examination between L4–L5 were 13 5°, 14 3°, and 2 2° and the translations 0 95, 10 29, and 1 23 mm for the three motions, respectively

The Eulerian rotations and the translations about and along the three coordinate axes for the third examination, performed 357 days postoperatively, are graphically shown in Fig 3 Significant motions between L5–S1 (marked **) were found during extension flexion and axial rotation Thus the rotations 1 7° and 0 3° about the x- and z-axes were registered in the case of extension-flexion with a translation of 0 87 mm along the z axis Axial rotation caused the negative rotations 1 3° about the

Table 4

Case 2 The total rotations and translations between the pairs of vertebrae in the three examinations

Segment pair	Days after operation	Lateral bending left-right		Extension flexion		Axial rotation left-right	
		Rot	Transl	Rot	Transl	Rot	Transl
L4-L5	109	4 4*	0 46**	5 7	4 12	1 0	0 28
	174	1 7	1 13	7 9	5 85	1 4	0 79
	357	13 5	0 95	14 3	10 29	2 2	1 23
L5-S1	109	0 3	0 62	3 3	1 24	0 2	0 43
	174	1 1	1 03	1 9	0 42	1 2	1 03
	357	0 5	0 46	1 8	0 97	1 4	0 23

* Unit degrees
** Unit mm

4 2° at lateral bending from side to side The simultaneous translation was 3 71 mm The corresponding rotation and translation for the other fused segments L4-L5 were 3 7° and 0 88 mm, respectively During the same motion the rotation was 4 3° and the translation 4 26 mm for the control segments L3-L4 Neither between L5-S1 nor L4-L5 was any significant total rotation or translation demonstrated during the second and third examinations, performed 174 and 275 days postoperatively The mutual rotations for the control segment L3-L4 were 2 3° and 2 9° at lateral bending left-right during the two examinations

The more detailed analysis of the motions for the third examination is accounted for in Fig 2, where the values for the operated segments that were significantly different from zero according to the precision test are marked (**) Significant rotations about the z-axis (stippled staples) were demonstrated for all three types of motion between L5-S1 Thus during lateral bending left-right the rotation was 0 7°, during extension-flexion it was 0 3°, and during axial rotation, 0 5° For L4-L5 no significant motion was found The control segment pair (L3-L4) moved 2 6° from side to side, 0 8° at extension-flexion and 0 6° during axial rotation about the z-, x-, and y-axes, respectively It is also noted that the rotation 0 8° about the y-axis was demonstrated during lateral bending from left ro right for the same segment pair

Case 2 The examinations of this patient, with spondylolisthesis L5-S1 are accounted for in Table 4 During the first examination, performed 109 days postoperatively, the rotation was 3 3° and the translation 1 24 mm between L5-S1 during extension-flexion, whereas the other motions were insignificant The other segment pair, L4-L5, also operated upon, rotated 4 4°, 5 7°, and 1 0° relative to each other during lateral bending, extension-flexion, and axial rotation, respectively The second examination which was undertaken 174 days after the operation, caused the

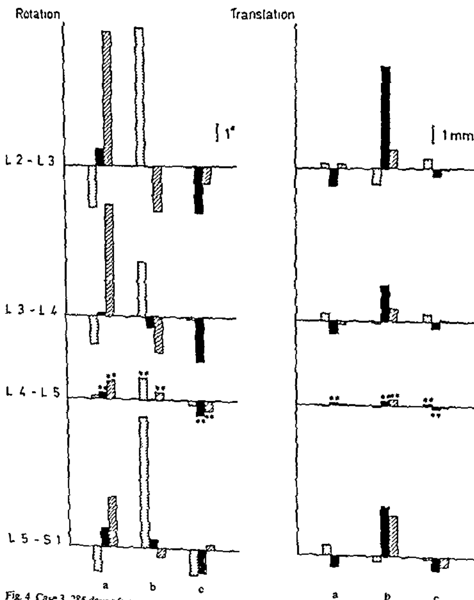


Fig. 4 Case 3 285 days after operation The Eulerian rotations and the transl[illegible] vertebrae at the th[illegible] dif[illegible] seg[illegible]

Discussion

The mean errors of *rigid body fitting* were of the same magnitude as the measurement errors (Table 1) *There was evidence* of a slight motion between the indicators in L2 and L3 of Case 3 during *axial rotation* This is, however, unimportant for the

Table 5

Case 3 The total rotations and translations between the pairs of vertebrae in the three examinations

Segment pair	Days after operation	Lateral bending left–right		Extension flexion		Axial rotation left right	
		Rot	Transl	Rot	Transl	Rot	Transl
L2–L3	116	6 6*	1 23**	4 3	3 63	1 3	0 26
	182	5 2	0 20	7 7	5 67	3 5	0 51
	285	8 4	1 13	8 7	6 21	3 0	0 76
L3–L4	116	6 1	1 26	1 5	0 91	0 7	0 25
	182	4 4	0 27	4 2	2 95	3 1	0 42
	285	6 9	0 95	4 0	2 30	2 7	0 61
L4–L5	116	1 8	0 09	0 8	0 35	0 7	0 12
	182	1 3	0 10	1 3	0 73	1 3	0 16
	285	1 2	0 19	1 5	0 52	1 1	0 26
L5–S1	116	5 2	2 03	4 2	2 10	0 7	0 27
	182	1 9	0 78	11 1	5 49	1 3	0 48
	285	3 6	0 95	8 1	3 93	2 1	0 94

* Unit degrees
** Unit mm

y-axis and 0 5° about the z-axis The rotations 13 2°, 14 1° and −1 1° about the z-, x-, and y-axes were found between L4–L5 during lateral bending, extension flexion, and axial rotation, respectively In addition, the rotation −2 9° about the y axis was encountered at lateral bending left–right

Case 3 This patient, operated on L3–S1 because of degeneration of the fourth lumbar disk, is accounted for in Table 5 It is seen that extensive motions were obtained for L2–L3, L3–L4, and L5–S1 during all three examinations Though limited the rotations between L4–L5 were, however, highly significant ($p<0.001$) during all examinations They vary between 0 7° and 1 8°, both values obtained during the first examination (116 days postoperatively) The rotations registered during the examination performed 285 days after the operation are 1 2°, 1 5°, and 1 1° for lateral bending left-right, extension-flexion, and axial rotation, respectively

The motions obtained 285 days postoperatively in terms of Eulerian rotations and translations, about and along the three coordinate axes appear in Fig 4 Lateral bending left–right, extension-flexion, and axial rotation caused the rotations 1 1°, 1 3°, and 0 9° about the z-, x-, and y-axes, respectively, for L4–L5 At the other levels of operation, L3–L4 and L5–S1, movements of the same magnitude exist as at the control segment pair L2–L3

that in determining the x- and y-coordinates This less precision of the z-coordinates influences the rotations about the x- and y-axes but does not affect the rotation about the z axis In addition, the discussed unfavourable position of the indicators contributes to the rotational error about the x axis. Thus only presentating the total rotations renders it less possible to discriminate the rotations about the z-axis

In Case 2 a comparatively stable interval between L5–S1 was obtained, while unrestricted movements at the third examination existed at the other operated interval A comparison between the total rotations (Table 4) and the Eulerian rotations (Fig 3) shows that the significant total rotations for extension-flexion and axial rotation are mainly explained by significant rotations about the x-axis in extension-flexion and about the y-axis in axial rotation The significant total translation at extension-flexion is due to a significant translation along the z-axis

Though there was no bony fusion, Case 3, operated at L3–S1 because of degeneration of the disk between L4–L5, had only little power of motion at the diseased level The total motion at this level was highly significant (p 0 001) in all three examinations The detailed analysis for all three types of movement at the third examination (Fig 4) also displayed highly significant motions about the three axes

Thus, among the seven operated segment pairs only one healed with a solid union, i e L4–L5 in Case 1 Three operated intervals, L4–L5 in Case 2, L3–L4, and L5–S1 in Case 3, have preserved their mobility Though still mobile, the primarily diseased intervals L5–S1 in Cases 1 and 2, and L4–L5 in Case 3 became comparatively rigid This indicates that it is difficult to obtain a complete bony union between the fused vertebrae in the lumbosacral spine The reason for this is unknown Careful technique was used throughout the exploration and decortication and there was generous transplantation of spongious bone In addition to the surgical technique, the other known factor of importance in bone healing is immobilization The results in these cases suggest that external immobilization should perhaps be reinforced by an internal fixation Another conclusion is that bony union is not needed for the patients' subjective satisfaction, a fibrous union may suffice (SHAW & TAYLOR 1956) Surgical intervention should perhaps be confined to the diseased intervals as claimed by CLEVELAND et coll as early as in 1948 They also advocated that fusion always should extend to include the sacrum This latter opinion is not supported by the present results and further investigations are needed concerning these matters

SUMMARY

Three cases operated upon with posterolateral fusion in the lumbosacral spine have been subjected to a kinematic postoperative analysis with the aid of a [illegible]
grammetr[illegible]

present discussion as these segments moved freely relative to each other and relative to L4, respectively

The difference in precision in determining rotation angles and translations between the different segment pairs in the three patients (Table 2), is explained by the position of the indicators and the distance between the segments Thus two indicators were placed in the neural arch anterior to the lysis on one side of the fifth vertebra of Cases 1 and 2 and one indicator in the corresponding part of the arch on the contralateral side Therefore the two indicators on the same side were necessarily positioned close to each other This fact explains the lower degree of precision in the measurement of the rotation about the x-axis at the L4–L5 and L5–S1 levels in Cases 1 and 2 The distance between the level for the indicators in L5 and that for S1 was five times greater than the corresponding distance between L4 and L5 This greater distance constituting a 'lever arm' during the calculations, is the cause of the high standard errors in the measurement of the translations for the L5–S1 level In addition, it should be noted that the precision in the translation along the z axis is less than that for the other translations (SELVIK 1974, p 125)

The kinematic analysis of the two first patients showed that stability between the fused segments was not achieved at the first examination (109–111 days postoperatively), e g Case 1 rotated 3 7° between L4–L5 and 4 2° between L5–S1 on that occasion, and the rotations for the same segment pairs in Case 2 were 5 7° and 3 3°, respectively However, at the second examination, performed 174 days after operation, the power of mobility was little Thus no significant total rotation or translation ($p < 0\ 01$) was then found for the fused vertebrae in Case 1, and the motions were also diminished between L5–S1 in Case 2 Any notable difference of motion between the second and the third examinations of the two first patients was not found Thus 174 days after operation the stabilizing effect seemed to be established in these two patients Case 1 had no significant total rotation or translation between any of the operated segments, and in Case 2 a comparatively stable interval between *L5–S1* had been obtained The kinematic analysis of the third patient displayed highly significant motions at all three examinations without any notable difference between them

The Eulerian rotations and the translations about and along the three coordinate axes (Figs 2 to 4) were reported in order to give a more detailed analysis of the third examination Although the total rotations and translations did not demonstrate any significant motion in Case 1 between L5–S1 at that examination, there were significant rotations 0 7°, 0 3°, and 0 5° about the z-axis during the different motions, the values 0 7° and 0 5° actually being highly significant ($0 < 0\ 001$, Fig 2) There was no significant motion in any direction at the L4–L5 level during the third examination The difference between the two methods in ability to detect motions is partly explained by the fact that the precision in determining the z-coordinates is less than

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CHRONIC MULTIFOCAL CLEIDO-METAPHYSEAL OSTEOMYELITIS OF CHILDHOOD

Report of a case

F P PROBST

Nonspecific hematogenous osteomyelitis was a serious disease in the pre-antibiotic days, with a mortality of 20 to 40 per cent for patients with courses classified as 'acute' (HALL & SILVERSTEIN 1963, MARTIN et coll 1969), and with a high frequency of lasting defects of varying severity Since then, the mortality has dropped to 1 to 1 5 per cent (MARTIN et coll, FLACH 1970) The improvement in the prognosis also affects the sequelae Permanent disability can now often be avoided or kept at a minimum if adequate therapy is instituted soon after the first general or local symptoms appear This is a strong argument for aiming at an early provisional or confirmed diagnosis Radiology has hitherto contributed little to this particular problem, because osteolysis and periosteal bone formation are seldom recognizable before the end of the first week, and usually only later, after 12 to 14 days The first observable radiographic abnormality, however, is soft tissue swelling adjacent to the osteomyelitic process, but only in exceptional cases is this observed as early as the second to fourth day (GIEDION 1960, 1970), and even then its detection may depend on the thoroughness of the examination So far, the object of radiographic examination has not been to provide justification for starting antibiotic therapy, but merely to confirm a tentative diagnosis (which must be based on clinical and bacteriologic evi-

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ZUSAMMENFASSUNG

Drei Fälle, die mit einer postero lateralen Fusion der Lendenwirbel operiert worden waren, wurden einer kinematischen postoperativen Analyse mit einer rontgenologischen stereophotogrammetrischen Methode unterzogen Die primär pathologischen Abschnitte blieben relativ steif trotz einer signifikanten Rest-Beweglichkeit, bei zwei der Patienten nicht bis zu 174 Tage postoperativ Drei Niveaus der Operation zeigten eine uneingeschrankte Rest-Beweglichkeit

RÉSUMÉ

Trois malades ayant subi une fusion postéro laterale de la colonne lombo sacree ont ete soumis a une analyse cinématique post-operatoire au moyen d une méthode radiologique stéréophotogrammétrique Les articulations intervertébrales primitivement atteintes sont devenues relativement rigides malgré la persistance d'une importante mobilité residuelle chez 2 de ces malades examinés 174 jours après l operation A 3 niveaux operes la mobilite résiduelle n'etait pas réduite

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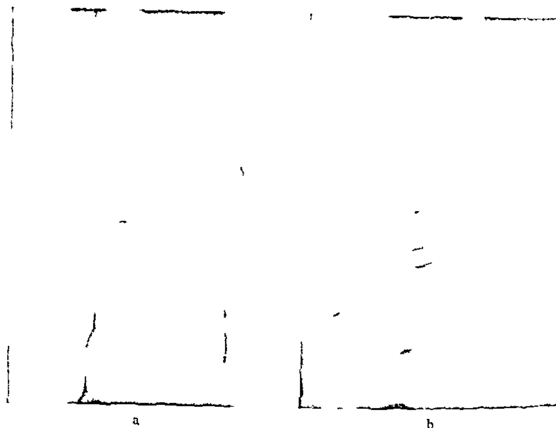
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Fig 2 Left ankle eight months after fig 1 b A p view The osteolytic area in the distal tibial metaphysis is still confined to the anteromedial part of the bone No distinctly visible periosteal reaction along adjacent parts of the bone surface The destruction of bone in the fibular metaphysis has become larger and the previous sclerotic margins have disappeared Marked cuff of new-formed periosteal bone This process at least has become reactivated

It should be borne in mind that each osteomyelitis pursues its own course, and that no two cases are alike in all respects It might be said that they all lie somewhere along a scale ranging from the most fulminant, septic form to the mildest type, which can never be verified because it is cured before producing radiographic abnormalities The majority of cases however, can be categorized in conventional terms However, the case presented here is different

Case report

The patient was a girl who at the age of 7 years began to complain of pain in both ankles and of feeling abnormally tired She had a subfebrile temperature, with occasional peaks reaching 40 C A blood culture was negative The ESR was 53 mm/h Roentgen examination demonstrated metaphyseal changes in the lower tibial and fibular ends on both sides suggestive of osteomyelitis She was treated with Lincocin (Upjohn) for 2 weeks and with Fucidina (Lovens Denmark) for a further 14 days After a temporary improvement, an exacerbation of the inflammatory process occurred at both sites only 2 weeks after the completion of therapy The ankles became more tender and swollen and radiography revealed progress of the bone changes Lincocin therapy was started again and continued for 8 months She responded well to this therapy and was relatively free from discomfort during the summer and autumn except for some ankle stiffness and a limping gait After 11 months dermatosis of both feet developed, which was diagnosed as pustulosis palmoplantaris Some weeks later she was readmitted to the hospital because of increasing pain in the ankles In addition, she complained of pain in her left knee and right clavicle Her temperature was raised but never exceeded 38°C She also had occasional chills Blood cultures were again negative The ESR was 60 mm/h Serologic examinations including the AST ASTA Widal s test and the ANF were normal The radiographic findings in this



a b

Fig 1 a) Right ankle, four months after onset of local symptoms A p view b) Left ankle six months after onset of symptoms Oblique view Multiple small, rounded bone defects in the lower metaphyses of the crural bones close to the growth plates The osteolytic lesions have partly sclerotic margins Periosteal reaction with formation of layers of bone where the process has broken through the cortical bone

dence), to localize the process, to establish its extent within the affected bone, to follow its progress and regression and finally to establish a cure

It is now generally believed that the character of osteomyelitis has changed during the antibiotic era, not so much with respect to the causative bacteria, since staphylococcus aureus is still the agent most commonly found in positive cultures, but more so with respect to its clinical course The stormy courses of former times are rarely met today, the disease often running a more insidious and subacute course Obviously, this is due to some extent to the influence of antibiotic therapy but the same tendency has been demonstrated in primarily untreated series (HARRIS & KIRKALDY-WILLIS 1965, ROBERTSON 1967), and this might be explained by weakened virulence of the bacterial strains (Editorial, Brit med J 1967) A nonspecific osteomyelitis should normally be cured within a reasonably short time, within 3 or 4 months according to FORSELL (1974) Inadequate therapy may prolong the time for effecting a cure and cause the disease to run a secondary, chronic course In some cases, an osteomyelitic process may be chronic from the beginning, such a course might be difficult to distinguish from the secondary chronic type with a relatively mild subacute onset

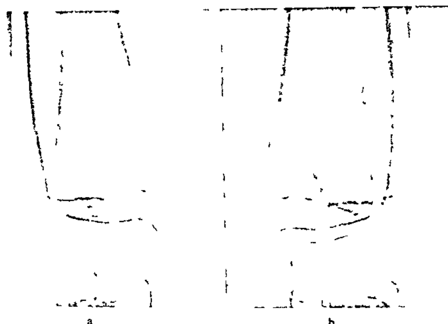


Fig 4 a) Left and b) right ankle two years after onset of symptoms A p views (Xeroxes reversed) The osteomyelitic processes along the metaphyseal surfaces of all 4 growth plates appear fairly well confined by sclerotic margins No discernible periosteal reaction but a soft tissue swelling is distinctly visible This in addition to slight local symptoms indicates that the process was still smouldering

hand, several exacerbations occurred during continuous long term treatment Whatever the factors responsible for this remarkable course may have been, the case represents a special clinical type of osteomyelitis To the writer s knowledge, only the case reported by KEIPERT & CAMPBELL (1970), those of GIEDION et coll (1972), and that of GUSTAVSON & WILBRAND (1974) are identical or essentially similar GIEDION et coll recognized the special nature of this form of osteomyelitis, and regarded it as a clinically definable entity, called by them subacute and chronic symmetrical osteomyelitis Microscopically, the plasmacellular variety of chronic osteomyelitis (UEHLINGER 1952 EXNER 1970, SIEBENMANN 1970) was found in 3 of their 4 cases The present case did not meet the criteria for plasmacellular osteomyelitis since only a few plasma cells were found scattered in the material obtained from the clavicle (second biopsy)

Conclusions

This case and the few cases reported in the literature suggest the following features to be characteristic for this type of osteomyelitis (1) Chronicity, i e a protracted course exceeding 'normal cure time (2) Involvement of more than one, sometimes many sites simultaneously and successively (3) Exacerbations, or relapses after



Fig 3 Right clavicle, almost twelve months after onset of local symptoms More than two-thirds of the clavicle have been destroyed and substituted by irregularly arranged new formed bone substance The new bone has grown to more than twice the ordinary thickness of the bone and is enveloped by a partly defective periosteal shell

initial period appear in Figs 1 and 2 A biopsy from the right clavicle revealed osteoclasia and abundant fibrotic tissue, but no conclusive evidence of inflammation These findings were considered a residual state of a nonspecific inflammatory process During the following summer and autumn she received long-term treatment with Lincocin, and felt quite well However, several episodes of exacerbation of her skin disease occurred, and these were always followed by increased pain and swelling in the affected regions Conversely, the regression of the skin changes was regularly accompanied by improvement of her bone complaints.

About 2 years after the onset of the disease, the process in the clavicle flared up and resulted in marked thickening of this bone (Fig 3) She was transferred to this hospital Her general condition was good but her ankles were swollen and tender on palpation She could walk cautiously without obvious limping but was unable to run or jump The films of her ankles taken on that occasion appear in Fig 4 A skeletal survey showed similar but less advanced abnormalities in several other regions such as the upper metaphyses of both tibias, the lower metaphysis of the left femur, and the distal metaphyses of two metatarsal bones She also complained of pain and tenderness over the distal ends of the right radius and left third metacarpal bone Roentgen examination revealed metaphyseal destruction at both sites (Fig 5) Although information was lacking as to the exact onset of these clinical symptoms, the clear-cut bone destructions and the presence of at least two periosteal bone layers on the ulnar aspect of the radius indicated that the processes were of recent origin A biopsy from the right clavicle suggested nonspecific inflammatory changes Cultures from the biopsy specimen, and repeated blood cultures including anaerobic cultures, remained negative An extensive search for an immunologic defect was unsuccessful The child was then dismissed Nine months later she was on long-term treatment with Lincocin and relatively well but not cured

Discussion

The present case showed considerable differences from the features that are usually encountered in hematogenous osteomyelitis The process occurred multifocally — in twelve sites—and affected loci within bones simultaneously and successively The disease has been, and still is, chronic with an insidious onset and several exacerbations during its course. Because of the failure to identify the causative agent it is difficult to assess the adequacy of the therapy applied or how it may have influenced the course The treatment was obviously not effective enough to cure the disease but seems to have kept the initial process and the relapses under control On the other

bakteriellen Angreifer und den Abwehrmechanismen wiedergibt Das Aufflammen eines alten Prozesses und dessen Streuung in neue Stellen kann auf eine vorübergehende Storung des Gleichgewichts zuruckgefuhrt werden

RÉSUMÉ

Presentation d un cas d ostéomyélite chronique multifocale hématogène chez un enfant Ce cas représente une forme clinique spéciale et bien défime de cette affection qui traduit de façon évidente des relations plus ou moins équilibrées entre l agresseur bactérien et les mécanismes de défense Les réveils de processus anciens et la dissémination à de nouvelles localisations peuvent etre imputés à un déséquilibre temporaire

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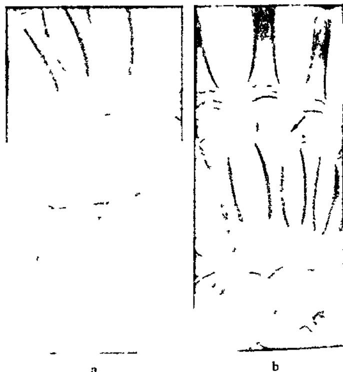


Fig 5 a) Right and b) left hand These films were taken on the same day as those in Fig 4 Fresh osteolytic processes in the metaphyseal ends of the right radius and third metacarpal bone (→) A delimiting bone sclerosis at both sites Two layers of new-formed periosteal bone

varying intervals, at sites that were apparently cured (4) The sites of predilection are the same as in acute or subacute hematogenous osteomyelitis of childhood and adolescence, namely the metaphyses of long or short tubular bones The medial ends of the clavicles are also preferred sites (5) At microscopy, 'plasma-cellular osteomyelitis' may be encountered, although not invariably (6) Etiologically, the process may be caused by the usual bacteria, but as a rule no bacteria are found in cultures from the blood, nor in the biopsy material In the latter case the effectiveness of an arbitrarily chosen antibiotic agent cannot be predicted but can be measured only in terms of the clinical response Regular roentgenographic examinations play an important part in the management

SUMMARY

A case of chronic, multifocal hematogenous osteomyelitis in a child is described It represents a special, well-defined clinical variant of this disease, which obviously reflects a more or less balanced relationship between the bacterial aggressor and the defense mechanisms Exacerbations of old processes, and spread to new sites, can be ascribed to a temporary imbalance

ZUSAMMENFASSUNG

Ein Fall mit einer chronischen, multifokalen, hamatogenen Osteomyelitis bei einem Kind wird beschrieben Dieser Fall repräsentiert eine spezielle, gut abgegrenzte klinische Variante dieser Erkrankung, die ein mehr oder minder deutliches Gleichgewicht zwischen dem



Fig 1 Typical spherical enlargement of the right maxillary sinus caused by a large follicular cyst Tomography in the a p projection

In spite of statements to the contrary in the literature, our experience, gained from examination of a large series of patients, would allow a safe distinction between cysts and malignant tumours in the majority of cases

Material and Method

The material consisted of 41 cases aged 15 to 79 years, the majority being over 60 and examined between 1969 and 1974 All presented extensive changes of the maxillary sinus on roentgen examination Each patient was examined with conventional technique supplemented by hypocycloidal tomography, the sections being 5 mm apart In all cases the diagnosis was confirmed at operation and at microscopy There were 23 cases of malignant lesions (21 carcinomas, 1 plasmocytosarcoma and 1 reticulo-cellular sarcoma), 13 cysts, 1 pleomorphic adenoma, 1 papillomatosis and 3 inflammatory lesions

The films were analysed without access to the results of microscopy The grouping of the patients was based on the following criteria

1) Cystic lesions are characterized by bone atrophy and soft tissue abnormalities at the margin of defective bone Furthermore, expansive growth of a cyst may displace the surrounding bone (Fig 1)

2) A malignant lesion should be suggested provided there is a well defined area of destruction and soft tissue abnormalities extending beyond the bony margin, or if irregular bone destruction with small 'islands' of remaining bone within the soft tissue mass is present However, it may be impossible radiographically to exclude osteitis or necrosis of bone following irradiation A soft tissue mass present on both sides of apparently intact bone may indicate a malignant lesion although an inflammatory condition is a more common cause

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RADIOLOGIC DIFFERENTIATION BETWEEN CYSTS AND MALIGNANT TUMOURS OF THE MAXILLA

U. ERASMIE and M. HAVERLING

The different radiologic apperances of cysts and malignant tumours of the maxilla were analysed by SONESSON (1950). In typical cases he found the differentiation simple. This was commonly the case when the tumour produced large irregular destructive lesions of the facial skeleton. He considered, however, that cysts sometimes may cause destructions very similar to those of malignant lesions. He also emphasized the importance of a refined technique which may include an examination of the maxillary sinus with contrast medium.

MÅRTENSSON (1955) points out that only histology can provide a safe diagnosis since malignant tumours may not invariably produce detectable destructions on roentgen examination while large maxillary cysts may cause destructive lesions otherwise considered characteristic of malignancy. In addition the mucous membrane of a cyst may become malignant.

JING (1970) states that a malignant lesion often is present (1) when, following adequate anti-infectious therapy, lesions remain in one or several sinuses, (2) when a soft tissue mass originating from a nasal or paranasal cavity infiltrates and permeates the bony wall of an adjacent cavity and (3) when sclerosis of the bone appears at the margin of destruction. He also points out that absence of bone destruction is no evidence of a benign condition.

Submitted for publication 15 January 1975



a



b



c

F g 3 Cyst c les on n r ght max llary s nus. a) A p project on R ght maxillary s nus f lled by soft t ssue mass bulg ng into the nasal cav ty b) Ax al project on Atrophy of the anterior wall of the r ght max llary s nus (arrows) c) Tomography Soft t ssue mass bulg ng nto the right nasal cav ty from adjacent max llary s nus No soft t ssue abnormal ty on the oppos te s de of seem ngly normal bony structures



F g. 4 On convent onal project ons max llary carcinoma may appear as an nnocent les on Mucous membrane swell ng in both max llary s nuses Mal gnant growth on the left s de as revealed in F gs 5 6

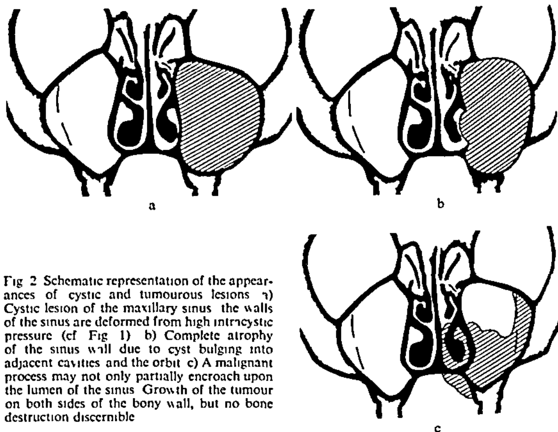


Fig 2 Schematic representation of the appearances of cystic and tumourous lesions a) Cystic lesion of the maxillary sinus the walls of the sinus are deformed from high intracystic pressure (cf Fig 1) b) Complete atrophy of the sinus wall due to cyst bulging into adjacent cavities and the orbit c) A malignant process may not only partially encroach upon the lumen of the sinus Growth of the tumour on both sides of the bony wall, but no bone destruction discernible

3) Lesions confined to a paranasal cavity not involving the adjacent bone fail to be differentiated on simple radiography provided that examination with contrast medium or scintigraphy of the facial skeleton (BERGSTEDT 1975) is not carried out most often the lesions turn out to be of inflammatory origin

Results On application of these criteria 24 cases were placed in the group of malignant tumours, 13 in that of cysts, while 4 were considered doubtful After further analysis of the latter, 2 cases were classified as carcinomas and 2 as cystic lesions

On comparison with the reports of pathology, the diagnosis was confirmed in 23 out of the 24 cases classified as malignant tumours in one only inflammatory abnormalities were revealed All 13 cases characterized as cysts were verified As to the cases of uncertain diagnosis, although classified as malignant, one proved to be an infectious lesion and the other that of a papillomatosis The final diagnosis of the 2 other uncertain cases classified as cysts was pleomorphic adenoma and sinuitis, respectively

Discussion

The value of radiography in differentiation between cysts and malignant tumours is a matter of controversy MÅRTENSSON considered the radiographic diagnosis of no



Fig 6 Same case as in Figs 4 5 Tomography in a p projection Upper row destructions in left facial skeleton. Lower row soft tissue mass on both sides of seemingly intact bone and growth of tumour far beyond margin of bone destruction

lesions were classified as tumour growths admittedly two of them were referred to the tumour group with much hesitation, while the third case was entirely misinterpreted Osteonecrosis secondary to osteitis was present in this case Thus, a differentiation between a bone destruction caused by a tumour or by an inflammatory lesion seems to be impossible

Conclusion In the present material examined with conventional radiography and with hypocycloidal tomography it was possible in most cases, to differentiate between cysts on the one side and malignant tumours and inflammatory lesions on the other Proposed criteria of differential diagnosis were of decisive value for the analysis of maxillary lesions

SUMMARY

Analysis of 41 cases with large maxillary lesions (23 malignant tumours 13 cysts and 5 other lesions) with the aid of special criteria based on the radiologic appearances of various lesions to distinguish cysts from malignant tumours and inflammatory processes

ZUSAMMENFASSUNG

Eine Analyse von 41 Fallen mit ausgebreiteten Läsionen der Maxilla (23 maligne Tumoren, 13 Zysten und 5 andere Läsionen) wurde mit Hilfe spezieller Kriterien vorgenommen um Zysten von malignen Tumoren und inflammatorischen Prozessen zu unterscheiden Diese stutzen sich auf das rontgenologische Bild der verschiedenen Läsionen

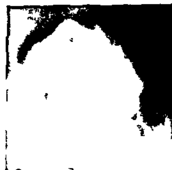


Fig 5 Same case as Fig 4 Special axial projection and intra oral film Destructive lesions are revealed in the alveolar processes

significance, the only reliable examination being microscopy but SONESSON points out some possibilities to differentiate maxillary lesions radiologically JING finds that conventional radiography often may establish the diagnosis of a malignant tumour, he states that soft tissue growth on both sides of a thin wall of the facial skeleton often is of malignant nature

Tumours and cysts grow differently The tumour infiltrates the adjacent tissues while cysts grow by expansion (Fig 1) Soft tissue growth on both sides of an apparently normal bony wall is in favour of a tumour, small radiographically undetectable areas of destruction will permit the tumour cells to spread to the opposite side of the wall These bone lesions may be hard to demonstrate even with the aid of refined tomographic technique Cystic lesions may attain a large size causing substantial changes of the facial skeleton and may resemble malignant lesions In these cases, however, soft tissue abnormalities on the opposite side of the seemingly intact skeletal wall are not evident Even if small areas of destruction do exist the cyst does not as a rule penetrate the bony wall unless the wall is totally atrophied with a defect large enough to allow the cyst to bulge in an even and rounded formation A tumour usually presents with a polycyclic or irregular border of the soft tissue mass

Frequently a malignant tumour of the maxillary sinus, when discovered, has spread to one or more facial cavities the tumour cells do not respect the integrity of bony structures A cyst on the other hand is usually limited to its cavity of origin for a considerable period, following expansion of the cyst the outline of the cavity will be deformed and appear more or less spherical (Figs 1, 2)

Re-evaluation of the films was based on the proposed guide-lines Thirteen lesions with reasonably characteristic cystic appearances were easily distinguished (Fig 3) Also the malignant tumours could be distinguished without difficulty although a case of inflammatory lesion was wrongly referred to this group (Figs 4, 5, 6)

The diagnosis was uncertain in four cases One of them turned out to be a benign tumour, one a polyposis of the nasal cavity and two ordinary sinuitis In an additional case classified as a cyst but with a final diagnosis of a sinuitis the inflammatory process might have originated in a cyst

It appeared possible to differentiate cysts from other lesions of the maxillary sinus such as malignant tumours and inflammatory processes Three cases of inflammatory

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SIMULTANEOUS ARTHROGRAPHY OF THE TALOCRURAL AND TALONAVICULAR JOINTS IN CHILDREN

I Technique

B SAHLSTEDT

Abnormalities of the talus comprise an important feature of several foot deformities, both congenital and acquired, including club foot Dissections on infants with club foot generally reveal talar deformities, in particular flattening of the trochlea and accentuated medial and plantar deviations of the neck and head (ADAMS 1866, KOCHER 1879, PARKER & SHATTOCK 1884, SCUDDER 1887, NICHOLS 1897, IRANI & SHERMAN 1963, SETTLE 1963, REIMANN 1967, FJELDBORG 1971) The navicular bone is usually dislocated medially and towards the sole of the foot Obliteration of the ankle recesses has also been described A thorough knowledge of the abnormal anatomy in this deformity is of fundamental importance for the choice of therapeutic method and the prognosis

At birth ossification centres are usually present in the talus, calcaneus and cuboid, but not until the age of about three years are they found more or less regularly in all bones of the foot (VOGT & VICKERS 1938, SCHMID & HALDEN 1949, HENSSGE 1968, HOERR et coll 1962) Thus, radiography of the foot skeleton in an infant is rendered difficult As pointed out by SETTLE (1963), it is not possible to evaluate the outline of the talus from the appearance of the ossification centres Thus by conventional

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RÉSUMÉ

Les auteurs ont analysé 41 cas de grosses lesions maxillaires (23 tumeurs malignes 13 kystes et 5 autres lesions) en s'aidant de critères speciaux basés sur les aspects radiologiques des différentes lésions pour distinguer les kystes des tumeurs malignes et des lesions in flammatoires

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Contrast medium In most clinical arthrographies Urografin 45 or 60 % was used In a few cases Rayodal (BJÖRK et coll 1970) was tried The iodine content was equivalent to that of Urografin 45 %, but Rayodal appeared to be absorbed somewhat more slowly, allowing additional films to be exposed No detailed comparison of the contrast media was made

Puncture technique

As the available water soluble contrast media are rapidly absorbed, the two joints had to be examined in one session, and relatively fast The punctures were performed with a fine needle to which was attached a soft, compressible tube, with few exceptions a 21 gauge scalp vein needle (0 8 mm × 19 mm) was used The contrast medium was injected from an infusion aggregate suspended about one metre above the examination couch This had been found to give a suitable infusion pressure and to reduce the risk of extraarticular leakage of contrast medium

Talonavicular joint Puncture of this joint may be difficult and time-consuming and is therefore performed first In club foot the navicular bone is often dislocated towards the sole and medially and is located close to the medial malleolus The joint is then difficult to palpate Therefore the puncture should be performed under fluoroscopic control and is most easily done from the dorsal aspect of the foot, with the needle directed somewhat disto-medially to the ossification centre of the talus As a rule it is easily felt when the needle has slipped into the joint

If the navicular bone is not dislocated, the talonavicular joint may alternatively be punctured from the medial side of the foot The puncture needle is then inserted anterior to the tip of the medial malleolus, under fluoroscopic control, in the direction towards the anterior part of the talar ossification centre

The needle is inserted with the connection tube closed off When the position of the needle is estimated to be correct, the location of its tip is checked with a small amount of contrast medium, after which the tube is closed while the talocrural joint is punctured

Talocrural joint Usually this joint is easily felt on palpation The puncture is most easily performed medially from the anterior aspect but may be done without difficulty anywhere along the anterior margin of the joint When the position of the needle has been checked, the joint is filled with contrast medium from the infusion aggregate, via the connection tube, under fluoroscopy Manual injection is not advised, as it may give rise to extraarticular leakage of contrast medium The foot is moved passively in various directions to spread the contrast medium through the joint

When the talocrural joint has been filled satisfactorily, the talonavicular joint is filled also under fluoroscopy To prevent leakage of contrast medium through the puncture track, both needles are left in situ as long as they do not hinder exposures in the desired projections

radiography only the positions of the ossification centres and their mutual relationships are determined Even this is relatively unreliable, due to difficulties in finding reference points for reproducible standard projections

About 60 per cent of the surface of the talus is articular, and therefore by arthrography of the joints involving this bone a large part of its configuration is discerned

Arthrography of the ankle joint is a well established clinical procedure, which hitherto has been used mainly for examining ligament ruptures in adults (WOLFF 1940, HANSSON 1941, ARNER et coll 1957, BROSTRÖM et coll 1965, OLSON 1969) The arthrographic anatomy of the ankle in adults, and its variations, have been described in detail (LÜNING et coll 1968, HAAGE & FISCHEDICK 1973) This method has also been used for evaluating the ankle joint in congenital club foot in infants (BERTRAND 1947, POULAIN 1949, CABANAC et coll 1952)

Arthrography of the posterior subtalar joint was performed by MEYER (1973) in patients with post-traumatic pain, but has not come into general clinical usage

Arthrography of the talonavicular joint does not appear to have been applied clinically SETTLE (1963) realised the value of obtaining information on the position of this joint in relation to the trochlea in evaluating talar deformities in infants with club foot He described a method by which, in 3 cases, he opened the joint during the course of surgery for club-foot deformities, fitted a piece of sterile lead foil over the articular surface of the talar head, and exposed films in projections related to the position of the knee joint

In the present report a standardized technique for simultaneous arthrography of the talocrural and talonavicular joints is presented The method allows objective measurement of variables related to the shape of the talus and the orientation of its articular surfaces

Material

The material consisted of 165 arthrographies in children Of these clinical arthrographies, 91 were performed on congenital club feet, 24 on club feet of neurologic origin and 21 on feet with other deformities, predominantly calcaneovalgus and adductovarus Among patients with unilateral deformity, 29 arthrographies were also performed on the normal foot The age range of the patients was 3 weeks to 9 years The median age at the initial examination was about 1 5 years

Method

The children were usually examined under general anaesthesia Exceptions were made for older children with sensory loss in the lower extremities (spina bifida) For the puncture and the injection of contrast medium the child was placed supine on an examination couch Facilities for fluoroscopy with an image-intensifying television unit were available For the arthrography a film-focus distance of 80 cm and a focal spot size of 0 6 mm were used

Contrast medium In most clinical arthrographies Urografin 45 or 60% was used In a few cases Rayodal (BJÖRK et coll 1970) was tried The iodine content was equivalent to that of Urografin 45%, but Rayodal appeared to be absorbed somewhat more slowly, allowing additional films to be exposed No detailed comparison of the contrast media was made

Puncture technique

As the available water-soluble contrast media are rapidly absorbed, the two joints had to be examined in one session, and relatively fast The punctures were performed with a fine needle to which was attached a soft, compressible tube, with few exceptions a 21 gauge scalp vein needle (0 8 mm × 19 mm) was used The contrast medium was injected from an infusion aggregate suspended about one metre above the examination couch This had been found to give a suitable infusion pressure and to reduce the risk of extraarticular leakage of contrast medium

Talonavicular joint Puncture of this joint may be difficult and time-consuming and is therefore performed first In club foot the navicular bone is often dislocated towards the sole and medially and is located close to the medial malleolus The joint is then difficult to palpate Therefore the puncture should be performed under fluoroscopic control and is most easily done from the dorsal aspect of the foot, with the needle directed somewhat disto-medially to the ossification centre of the talus As a rule it is easily felt when the needle has slipped into the joint

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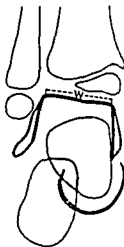


Fig 1 a) A p view of a norma ankle (boy aged 2 years 10 months) Contrast medium injected into the talocrural and talonavicular joints The puncture needles are left in situ to prevent leakage of contrast medium The central ray is tangential to the medial facet of the trochlea b) Measurement of the width of the trochlea (W)

a b

Projections

For demonstrating and evaluating the degree of talar deformity and surveying anatomic abnormalities in the talocrural and talonavicular joints in different types of foot deformity, films in exact, well defined projections are required The foot must therefore be positioned under fluoroscopy The following views were taken, all with a vertical beam and with the patient supine

1) A p view of the ankle (Fig 1 a) The foot is positioned in the conventional way with the lateral malleolus slightly more dorsal than the medial malleolus Under fluoroscopy the distal part of the fibula is projected close to the lateral margin of the tibia The central ray is tangential to the medial facet of the trochlea

2) A p view with the foot rotated inwardly (Fig 2) The lower leg is rotated inwardly about 20° The central ray is tangential to the lateral facet of the trochlea The small recess between the distal ends of the tibia and fibula is usually discerned best in this projection

3) The lateral view (Fig 3 a) is defined as the view in which the medial and lateral articular surface margins of the trochlea coincide as closely as possible to form one single arch The distal part of the fibula is projected over the dorsal aspect of the tibia The lateral view is usually taken with a medio-lateral beam direction but is sometimes easier to obtain latero-medially, due to the valgus orientation of the talus The mobility of the ankle and the variations in size of the ankle recesses are first assessed fluoroscopically Lateral views should be taken with the foot in maximum dorsiflexion and maximum plantar flexion

4) Dorso-plantar view of the foot (Fig 4 a) The sole of the foot is placed against the examination couch with the lower leg directed about 45° to the couch The foot is positioned so that the trochlea is oriented in the longitudinal axis of the cassette The talar trochlea is seen from above In the presence of a varus deformity a correct



Fig 2 A p view of inwardly rotated ankle Same child as in Fig 1 a The central ray is tangential to the lateral facet of the trochlea

projection is obtained if the lower leg is inclined medially, and *in a valgus deformity if it is inclined laterally* The trochlea must be well visible under the distal part of the tibia *In this projection* films centered on the talus as well as films including both the talus and the metatarsal bones were exposed

Film evaluation and method of measurement

The following variables are measured (1) Width of trochlea, (2) length of talus, (3) radius of trochlear curvature, (4) central angle of trochlear curvature, (5) plantar deviation of the talonavicular joint, and (6) medial deviation of the talonavicular joint

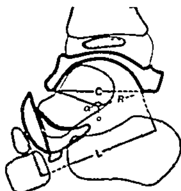
The width of the trochlea and the length of the talus form the basis of evaluation of age related factors

The width of the trochlea (W) is measured on the a p film of the ankle (Fig 1) This film also allows measurement of the valgus position of the trochlea, i e the angle between the normal of its articular surface and the longitudinal axis of the tibia On the a p film and on the a p film of the inwardly rotated foot, the angle of the medial and of the lateral articular surface, respectively, against the upper articular surface of the trochlea may be measured (Fig 2) Further, the two a p views give a general idea of the orientation of the talonavicular joint and of any abnormality of its articular surfaces

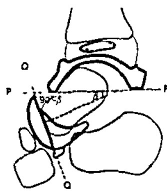
The length of the talus (L) is measured on the lateral film of the ankle (Fig 3 a, b) The curvature of the trochlea is approximated to the arc of a circle whose radius and midpoint are determined by means of stencils with a known radius The radius (R)



a



b



c

Fig 3 Lateral view Same ch ... line between the ta... of the talus and the... (C) is tangential to... protractor The curv... determined by means of a stencil with a known radius (R) c) Measurement of the plantar deviation (β) of the talonavicular joint The base-line P P is tangential to the anterior and posterior ankle recesses The base line Q Q of the talonavicular joint is drawn through the upper and lower capsular attachments of the joint and the plantar-oriented recess marking the borderline against the anterior subtalar joint In practice the angle between P P and Q Q (90 β) is measured and β is then obtained by subtraction

and central angle (α) of the trochlear curvature are constructed (Fig 3 b) The central angle is then measured with a protractor

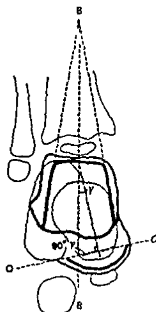
The plantar deviation of the talonavicular joint is also measured on the lateral film (Fig 3 a, c) Often the joint communicates with the anterior subtalar joint The borderline between the two joints may be difficult to establish but is usually indicated by a small recess oriented plantarward The plantar deviation is best expressed as the angle (β) between the base-line of the trochlea (extension of the chord) and the normal to the base-line through the talonavicular joint This angle then corresponds directly to the degree of plantar deviation

In abnormal cases in which the head of the talus deviates greatly in the medial direction, the talonavicular joint appears as a ring or an oval The base-line through the navicular facet is then more difficult to construct and measurement of the angle less exact

The medial deviation of the talonavicular joint is calculated on the dorso plantar view of the foot (Fig 4) and is best expressed as the angle between the longitudinal axis of the trochlea and the normal drawn to the base-line of the talonavicular joint

In the case of a prolonged dislocation of the navicular in the medial direction, the talonavicular joint becomes deformed and the articular surface of the talar head becomes flattened medially The flattened area then comprises the surface actually articulating with the navicular bone The orientation of the first metatarsal may also indicate the position of the navicular bone, at least in untreated cases (FJELDBORG 1971)





a b

Fig 4 Dorso-plantar view of the foot Same child as in Fig 1 a a) The talonavicular joint deviates slightly in the *medial direction* b) Measurement of the medial deviation (γ) of the talonavicular joint B – B is the h
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… easured and γ is then obtained by subtraction

The anterior and posterior ankle recesses are evaluated on films taken in maximum plantar flexion and maximum dorsiflexion The range of movement of the ankle joint is also estimated at the same time, most easily by lines drawn through the distal tibial epiphysis and the talar ossification centre A preliminary assessment of the mobility and of the variation in size of the recesses should be made under fluoroscopy

Results

Duplicate determinations were not possible in the clinical cases, but the measurability of the reported variables was good throughout

The reproducibility and validity of the measurements will be discussed in part II (HJELMSTEDT & SAHLSTEDT 1976)

Filling of adjacent joints and tendon sheaths Communication between the talocrural joint and the posterior subtalar joint has been reported in varying frequencies in adult clinical series (BROSTRÖM et coll 15 6 %, HAAGE 8 %, LUNING et coll 10 %, MEYER 12 %, REZEK 4–5 %)

In this clinical paediatric material such communication was observed in 14 of 99 deformed feet (14 %) and in one of 22 clinically normal feet

Communication between the talonavicular joint and the anterior subtalar joint was found in 64 deformed and 18 normal feet (65 and 82 %, respectively) Spontaneous filling of the calcaneocuboidal joint from the talonavicular joint was noted in 14 deformed and 5 normal feet (14 and 23 %, respectively) Spontaneous filling of the naviculocuneiform joints via the talonavicular joint occurred in one normal foot and 6 deformed feet In one patient (a 2 1/2-year-old girl with an adductovarus foot deformity), injection of contrast medium into the talonavicular joint resulted in filling of the subtalar, talocrural and calcaneocuboidal joints and the joints between the navicular and the cuneiform bones

In club foot with an excessive medial deviation of the talar head and medio plantar dislocation of the navicular, an erroneous appreciation of the position of the talo navicular joint may easily be obtained in attempts at puncturing from the medial side, when the joint between the navicular and the first cuneiform bone may be accidentally punctured In the clinical material this happened twice

According to reports in the literature, medio-plantar tendon sheaths can be filled via the dorsal recesses of the ankle joint (BROSTRÖM et coll 22 %, LUNING et coll 14 % MEYER 10 %) In the present clinical paediatric material medial tendon sheaths were filled in one normal foot and 20 deformed feet (20 %) In no case communication existed between the talocrural joint and lateral tendon sheaths

Accidental puncture of tendon sheaths on the dorsal aspect of the foot occurred four times

Technical errors Of 115 attempts at arthrography in 82 club feet, 10 (8 6 %) failed on account of difficulties in puncturing the talonavicular joint In normal and slightly deformed feet the punctures were always successful

Slight leakage of contrast medium around the needles or through the puncture tracks is relatively common and difficult to avoid, especially if several attempts at puncturing have been made However, leakage may be prevented by fluoroscopy of the influx of the contrast medium and by using a low infusion pressure One difficulty arises when the position of the needle is estimated to be correct and no contrast medium flows in This is often due to blockage of the tip of the needle by a piece of tissue By gentle compression of the infusion tube the infusion pressure is temporarily increased and the needle flushed If this is not successful, another attempt at puncturing must be made

Complications In one patient slight swelling and pain on weight-bearing occurred on the day after the examination These symptoms may have been due to leakage of contrast medium into the soft tissues

No infections and no allergic reactions were encountered No prophylactic antibiotics were given

Apart from transient bronchospasm in one patient, no complications from the anaesthesia occurred Depending on the circumstances, endotracheal intubation was performed in connection with the anaesthesia in some patients

Discussion

Estimation of the shape and orientation of the bones of the infantile foot from their ossification centres has been found to be impractical (SETTLE 1963) However, arthrography of adjacent joints is of considerable value in this respect In arthrography of the ankle joint in children with club foot, BERTRAND (1947) observed flattening of the trochlea of the talus POULAIN (1949) performed ankle arthrography in 64 children with congenital club foot, and found a hypoplastic ankle joint, often with obliteration of its anterior recess The height of the talar trochlea was reduced and the central angle decreased The examination was performed on children of ages 5 days to 7 years and included arthrography of 22 normal feet CABANAC et coll (1952) observed flattening of the talar trochlea on fluoroscopy in attempts at forced reduction of congenital club feet SETTLE (1963) realized the importance of assessing the relationship between the talonavicular and talocrural joints and also attempted arthrography of the former joint He emphasized the significance of exact projections

As mentioned previously in preliminary reports (SAHLSTEDT & HJELMSTEDT 1971, HJELMSTEDT & SAHLSTEDT 1973, SAHLSTEDT 1974), simultaneous arthrography of the talocrural and talonavicular joints allows demonstration of the talar deformity in congenital and secondary club foot and to evaluate individual components of the deformation such as flattening of the trochlea, increased plantar medial deviation of the neck and head, and secondary abnormalities of the head due to navicular dislocation The joint recesses obviously are easily assessed

Assessment of the curvature of the trochlear surface may be difficult in some cases Approximation to the arc of a circle is a practical and reliable method in small children In older children and adults the radius of the curvature in the anterior third of the ankle joint is smaller than that in the posterior part of the joint, which means that the curvature corresponds less well to the arc of a circle Further, it must be pointed out that assessment of this curvature demands a strict lateral projection If the foot is wrongly rotated on exposure of the film, an illusory flattening of the trochlea will occur

In ...

... ie talonavicular joint

... ° in the medial direc-

... is not reproduced exactly in profile in a correct lateral view The base-line through the joint is drawn through the dorsal and plantar capsular attachments towards the small plantar oriented recess which marks the borderline against the anterior subtalar joint (Fig 3 a, c) If the medial deviation of the articular surface is extreme, the joint is reproduced as an oval or a ring The base-line in question may then be more difficult to construct exactly

Assessment of the medial deviation of the talonavicular joint is usually easier (Fig 4) The base line necessary for the measurement is drawn along the upper capsular attachment of the joint, which as a rule is defined by the contrast medium In

some cases, however, the joint is less well outlined, and the measurement of the angle will then be less exact

For assessing the medial deviation of the talar head it is also essential to establish the longitudinal axis of the trochlea This requires an exact dorso-plantar view If the trochlea is too greatly inclined laterally or medially (valgus-varus) the margins of the articular surface are reproduced as arches, rendering it difficult to draw the necessary lines If parts of the ankle joint are obliterated, one or other of the articular surface margins may not become outlined by contrast medium The medial deviation of the talar head will then have to be assessed from the angle between the visible articular surface margin and the base-line through the talonavicular joint

With respect to the treatment of congenital club foot it is important that any deformation of the articular surface of the talar head resulting from a navicular dislocation be disclosed It is also of clinical interest to examine the non-utilized part of the joint surface so as to be able to assess the possibility of restoring the navicular bone to its normal position and also the risk of redislocation after such correction

The communication between an examined joint and the adjacent joints and tendon sheaths is of interest The difference between the normal and the deformed feet is most marked with respect to the communication between the talocrural and posterior subtalar joints and between the talocrural joint and the medio-plantar tendon sheaths The observed difference in frequency of such communication seems to be a true one (χ^2-test)

Theoretically the range of movement of the ankle joint may be estimated by comparing the central angles of the tibial and trochlear articular surface curvatures However, the true range of movement is best evaluated on lateral films taken with the foot in maximum plantar flexion and maximum dorsiflexion The sizes of the ankle recesses vary with different foot positions and therefore have to be assessed first by fluoroscopy

SUMMARY

A method is described by which simultaneous arthrography of the talocrural and talonavicular joints is performed on neonates and small infants with a high degree of success and a very low risk of complications From films exposed in exact, standardized projections valuable and highly reproducible information is obtained about the configuration of the talus, the shapes and mutual relationships of the joint surfaces, and any obliteration of the recesses One disadvantage of the method is the need for general anaesthesia

ZUSAMMENFASSUNG

Beschreibung einer Methode, die es ermoglicht mit grosser Zuverlassigkeit und einem niedrigem Komplikationsrisiko, simultane Arthorgraphie des oberen und vorderen Sprunggelenkes bei Neugeborenen und Kleinkindern vorzunehmen Von Filmen, die in exakten standardisierten Projektionen aufgenommen sind, konnen wertvolle und reproduzierbare

Informationen uber das Aussehen des Sprungbeins die Form und das gegenseitige Verhaltnis der Gelenkoberflachen und Obliteration der Rezessen erhalten werden Eines der Nachteile der Methode ist die Notwendigkeit einer Allgemeinnarkose

RÉSUMÉ

Description d une methode qui permet avec une grande proportion de succes et un faible taux de complication de faire simultanement une arthrographie des articulations tibio tarsienne et astragalo scaphoïdienne chez des nouveaux nés et des jeunes nourrissons Les films pris dans des projections exactes et standardisées donnent des informations utiles et reproductibles sur la configuration de l astragale la forme et les rapports des surfaces articulaires et sur l obliteration des recessus Un des inconvenients de cette méthode est la nécessite d une anesthesie genérale

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SIMULTANEOUS ARTHROGRAPHY OF THE TALOCRURAL AND TALONAVICULAR JOINTS IN CHILDREN

II Comparison between anatomic and arthrographic measurements

Å HJELMSTEDT and B SAHLSTEDT

A technique for simultaneous arthrography of the talocrural and talonavicular joints *in children* was described in part I (SAHLSTEDT 1976) The purpose of this part of the investigation was to establish to what extent measurements on the films correspond to measurements on anatomic specimens and furthermore to ascertain the reliability of the arthrographic method by duplicate determinations

Material and Methods

Arthrography was performed on 32 autopsy foot specimens from 19 children with no deformities of the feet The specimens were then dissected and various measurements were made on the talus Eleven of the children had died before the age of one month 3 at one to 6 months, 4 at 9 to 19 months and one at 34 months

The foot specimen was placed on a skull table for the arthrography The FFD was 70 cm and the focal spot size 1 2 mm A barium sulphate suspension 40 % (Micropaque) was used as contrast medium The following projections were used

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a p view of the ankle, a p view with the foot inwardly rotated, lateral view of the ankle, and dorso-plantar view of the foot (see part I)

Three series of films were exposed on each specimen Before the first series the talocrural joint alone was injected, before the second series both the talocrural and the talonavicular joints, and before the third series the posterior subtalar joint in addition to these two Triplicate determinations could therefore be made on measurement data related to the trochlea of the talus, and duplicate determinations on data related to the talonavicular joint and its position in relation to the trochlea Correction for magnification (6 %) was made The precisions of the measurements on the films were 0 5 mm and 1° For comparison with the anatomic measurement, the mean of the corresponding film measurements was used

The following variables were measured

a) The width (W) of the trochlea radiographic a p view of the ankle, anatomic distance between medial and lateral trochlear margins measured on the middle of the trochlea

b) The length (L) of the talus radiographic lateral view of ankle

c) The radius (R) of the trochlear articular curvature lateral view of ankle, radiographic and anatomic measurement with a stencil

d) The central angle (α) of the trochlear articular curvature lateral view of ankle

e) The angle between the medial and lateral articular surface margins of the trochlea (dorso-plantar view of the foot)

Schematic drawings demonstrating how to measure the variables a–e, j and k are shown in part I

f) The radius (r) of the talar head curvature in the lateral view radiographic and anatomic measurement with stencils (Fig 1)

g) The central angle (δ) of the talar head curvature in the lateral view (Fig 1)

h) The radius (r") of the talar head curvature in the dorso-plantar view radiographic and anatomic measurement with stencils (Fig 2)

i) The central angle (ε) of the talar head curvature in the dorso-plantar view (Fig 2)

j) The plantar deviation (β) of the talonavicular joint in relation to the base line of the trochlea lateral view

k) The medial deviation (γ) of the talonavicular joint in relation to the medial and lateral articular surface margins of the trochlea and to the bisector between these margins dorso-plantar view

l) The angle between the base line of the trochlea and the longitudinal axis of the talar neck lateral view, anatomic measurement only

m) The angle between the longitudinal axis of the trochlea and the axis of the talar neck dorso plantar view, anatomic measurement only

The anatomic measurements were performed on plaster casts of the dissected [illegible] as possible to the projec- [illegible] as measured on its *middle* part For this measurement, and also for measuring the length of the talus, vernier

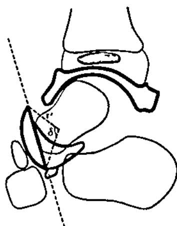


Fig 1 Lateral view of the foot Schematic drawing demonstrating how the radius (r') and central angle (δ) of the talar head curvature are measured This curvature is approximated to the arc of a circle, its midpoint is determined by means of a stencil with a known radius The base line is drawn along the capsular attachment of the talonavicular joint Small plantar-oriented recess between the talonavicular joint and the anterior subtalar joint

callipers were used The precision of the measurement was 0 5 mm The 32 talar specimens were fixed in the desired projection to a chart on which the different measurement points were then marked The angle between the medial and lateral articular surface margins of the trochlea was measured on the chart from these measurement points The radii of the trochlear and talar head curvatures were determined by means of stencils with known radii, with a precision of 0 5 mm The central angle of the trochlear and talar head curvatures in the lateral and dorso-plantar views were measured with a specially constructed protractor, the precision of the measurement being 5° The plantar and medial deviations of the talonavicular joint were measured on the chart from the measurement points, with a precision of one degree The angle between the base-line of the trochlea and the longitudinal axis of the talar neck, and the angle between the longitudinal axis of the trochlea and neck of the talus in the dorso-plantar view were measured in the same way

Results

a) Width (W) of trochlea The mean width obtained radiographically was 11 4 mm and SD 3 7 mm The standard error of observation (SE-obs, Mainland 1952) was calculated to be 0 3 mm After correction for magnification, the radiographic values were greater throughout than those obtained from the anatomic preparations, with a mean error of 0 8 mm This difference is statistically significant ($p = 0\ 05$) A good correlation existed between the results of the two methods ($r = 0\ 97$)

b) Length (L) of talus The mean radiographic value was 21 9 mm and SD 5 6 mm SE-obs was 0 48 mm The mean difference between the radiographic and anatomic values (0 05 mm) was not statistically significant ($p = 0\ 05$) Good correlation was found between the results of the two methods ($r = 0\ 98$)

c) Radius (R) of trochlear articular curvature The mean radius obtained radiographically was 7 5 mm and SD 2 2 mm SE-obs was 0 16 mm The values obtained from the films were generally greater than the anatomic values, the mean difference

being 0 40 mm This difference was statistically significant (p = 0 05) A good correlation was found between the results of the two methods (r = 0 96)

d) Central angle (α) of trochlear articular curvature The mean value obtained radiographically was 158° and SD 6 4° SE-obs was 3° The angles obtained from the films were, on the average, 4 5° greater than those obtained from the anatomic specimens This difference was statistically significant (p – 0 05) The correlation between the results of the two methods was weak (r = 0 03)

e) Angle between lateral and medial articular surface margins of the trochlea The mean angle obtained at the radiographic measurements was 25° and SD 3 2° SE-obs was 2 3° The radiographically obtained angle was 4 6° greater, on the average, than that obtained on the specimens This difference was statistically significant (p = 0 05) The correlation between the results of the two methods was relatively weak (r – 0 46)

f) Radius (r) of talar head curvature in the lateral view (Fig 1) The mean radiographic value was 5 9 mm and SD 1 8 mm SE-obs was 0 2 mm After correction for magnification the radius obtained from the films was, on the average, 0 4 mm smaller than that obtained from the specimens The difference was statistically significant (p 0 05) A strong correlation was found between the results of the two methods of measurement (r – 0 95)

g) Central angle (δ) of the talar head curvature in the lateral view (Fig 1) The radiographic measurement of this angle was uncertain The mean value was about 98 and SD about 11 SE-obs was 8 7° The angles obtained radiographically were, on the average, 13° greater than those obtained on the anatomic specimens, and the difference was statistically significant (p = 0 05) The correlation between the results of the two methods was weak (r = – 0 08)

h) Radius (r″) of the talar head curvature in the dorso-plantar view (Fig 2) The mean radiographic value was 6 7 mm and SD 1 9 mm SE-obs was 0 2 mm In comparison with the anatomic values, the radiographic radius was 0 3 mm smaller, on the average This difference was statistically significant (p – 0 05) A strong correlation existed between the results of the two methods (r = 0 96)

i) Central angle (ε) of the talar head curvature in the dorso-plantar view (Fig 2) The mean radiographic value was 117° and SD about 10° SE-obs 8 8° The angles obtained from the films were, on the average, about 10° smaller than those obtained from the specimens, the difference being statistically significant (p = 0 05) The correlation between the two results was relatively weak (r – 0 28)

j) Plantar deviation of the talonavicular joint in relation to the base-line of the trochlea This deviation is defined as the angle (β) between the base-line of the talocrural joint and the normal of the base-line of the talonavicular joint The mean radiographic value was 25 7° and SD 3 6° SE-obs was 2 5° The radiographically obtained angles were, on the average, 6 5° greater than those obtained anatomically This difference was statistically significant (p = 0 05) The results of the two methods were poorly correlated (r = 0 26)

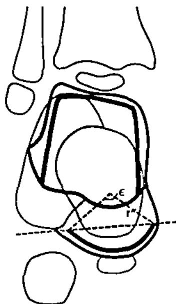


Fig 2 Dorso plantar view of the foot Schematic drawing illustrating how the radius (r″) and central angle (ε) of the talar head curvature (navicular facet) are measured The curvature is approximated to the arc of a circle, its midpoint is determined by means of a stencil with a known radius The base line through the navicular facet is drawn along the dorsal capsular attachment of the joint

k) Medial deviation of the talonavicular joint in relation to the trochlea This deviation is defined (1) as the angle between the normal of the base-line of the talonavicular joint and the medial and lateral trochlear margins respectively, and (2) as the angle between this normal and the bisector of the angle between the articular surface margins Radiographically, the mean angle between the normal and the medial trochlear margin was 2 5°, with SD 3 1° and SE-obs 1 9° The mean angle between the normal and the lateral trochlear margin was 27 0°, with SD 3 3° and SE-obs 1 7° The mean angle between the normal and the bisector of the trochlear articular surface margins was 14 8°, with SD 2 8° and SE-obs 1 4° In comparison with the angles obtained anatomically, the radiographic values differed, on the average by 4 0 , +0 04° and − 1 3 , respectively The former difference is statistically significant (p − 0 05) The coefficients of correlation between the two methods for the respective angles were r = 0 23, r 0 17 and r − 0 48, respectively

l) Angle between the base line of the trochlea and the longitudinal axis of the talar neck (lateral view, anatomic measurement only) The mean value was 26 8° and SD 3 8°

m) Angle between the longitudinal axis of the trochlea and neck of the talus (dorso plantar view, anatomic measurement only) The mean value was 27 7 and SD 4 9°

Discussion

Most of the anatomic specimens were small, as they came from infants who had died in the neonatal period Thus the results cannot be used without reservation as references for arthrographies on children above 3 years of age For instance, the

central angle of the trochlear curvature seems to decrease with age, from 160° in the embryo to 120° in the adult (BÖHM 1935) The normal values reported thus refer only to the age group of the present material or to tali within the same length or width range

The smallness of the specimens increases the precision of the measurements in certain cases Thus the choice of stencils for determination of the trochlear radius in small specimens is easy, as a change of the radius by one millimetre alters the curvature of the trochlea considerably Similarly, the curvature of the trochlea is more readily approximated to the arc of a circle in a small specimen than in a larger one, where some deviation from the arc occurs

In other cases the precision in measurements on small specimens is poorer For example, the central angle of the trochlear and of the talar head curvatures may be more difficult to measure on the films and still more difficult on the anatomic specimens This is evident from the standard error of observation

The anatomic measurements were performed in planes intended to correspond to the radiographic projections, which was rendered difficult by the complex shape of the talus The determination of the central angle of the talar head and of the trochlea, in particular, was more difficult on the anatomic specimens than on the films This probably explains the unsatisfactory correlation between the radiographic and anatomic values Moreover, due to difficulties in identifying the measurement points on the specimens, the precision of the anatomic measurements could not be raised above 5

The good reproducibility of most of the results of the arthrography may be explained by the use of non-absorbable contrast medium, which allowed unlimited time for arrangement of ideal projections with constant magnification The high degree of accuracy may therefore be regarded primarily as a reflection of the exactness of the measurement procedure In clinical practice probably an additional error of measurement exists due to difficulties in obtaining ideal projections and to a limited possibility of taking supplementary films

A good agreement was obtained between the anatomic and radiographic measurements and good reproducibility in duplicate and triplicate arthrographies for (a) the length of the talus and (b) the medial deviation of the talonavicular joint in relation to the lateral articular surface margin of the trochlea or to the bisector of the angle between the articular surface margins of the trochlea

This good agreement is probably due to the fact that minor discrepancies in the projection do not appreciably affect the length measurement, and that the measurement points were almost identical in the two methods The varying correlation between the methods in measurement of angles may probably be explained partly by the difference in the measurement precision

In duplicate and triplicate arthrographies good reproducibility was found and a high correlation between the radiographic and anatomic values, but not complete agreement, for (a) the width of the trochlea, (b) the radius of the trochlear curvature

and (c) the radius of the talar head curvature in the lateral and dorso-plantar projections

The agreement in duplicate and triplicate examinations shows that good radiographic reproducibility may be attained for these variables, and the high correlation between the radiographic and anatomic values demonstrates that the arthrography well reflects the anatomic conditions Discrepancies between numerical values obtained in the radiographic and anatomic measurements would seem to be due to differences in the methods of measurement

Relatively poor agreement—with a weak correlation—existed between the radiographic and anatomic values for (a) the central angle of the trochlear curvature, (b) the plantar deviation of the talonavicular joint, and (c) the angle between the articular surface margins of the trochlea (dorso-plantar view)

The poor agreement between the radiographic and anatomic values for these variables may probably be explained largely by difficulties in identifying the radiographic measurement points on the anatomic specimens Fairly good agreement was obtained, however, in duplicate and triplicate radiographic measurements of the central angle of the trochlear curvature, the plantar deviation of the talonavicular joint, and the angle between the articular surface margins of the trochlea The values would therefore seem acceptable as relative measures, at least for children below the age of 3 years

Poor agreement existed between the anatomic and radiographic values for (a) the central angle of the talar head in the lateral view, and (b) the central angle of the talar head in the dorso-plantar view

Large discrepancies were also noted in duplicate radiographic determinations, and this method is therefore unreliable for evaluating these central angles

Conclusions

Simultaneous arthrography of the talocrural and talonavicular joints under ideal conditions (autopsy specimens from children up to 3 years of age) has demonstrated that certain measurements concerning the talus and its adjacent joints may be performed on the films with a satisfactory degree of precision

Good agreement was found between the radiographic values and the values obtained on the anatomic specimens, as well as good radiographic reproducibility, with respect to the length of the talus and the medial deviation of the talonavicular joint However, the correlation between the two methods for measurement of the median deviation is fairly low

A high correlation but some numerical difference existed between the radiographic and anatomic values, and good radiographic reproducibility, with respect to the width of the trochlea and the radius of the trochlear articular curvature, and to the radius of the articular curvature of the talar head

Good or acceptable radiographic reproducibility in duplicate or triplicate examina

tions was found, but poorer agreement—with a low correlation—between the radiographic and anatomic values, concerning the central angle of the trochlear articular curvature, the angle between the articular surface margins of the trochlea, and the plantar deviation of the talonavicular joint

The poor agreement between the two methods of measurement for certain variables is probably due to difficulties in identifying the radiographic measurement points on the anatomic specimens

SUMMARY

Simultaneous arthrography of the talocrural and talonavicular joints was performed on 32 autopsy foot specimens from 19 children of ages up to 3 years Measurements concerning the size and shape of the talus were made on the films and the results were compared with corresponding measurements made on the anatomic specimens The differences between the results and the reliability of the radiographic method as analysed by duplicate and triplicate examinations are discussed

ZUSAMMENFASSUNG

Simultane Arthrographie des oberen und vorderen Sprunggelenkes wurde an 32 Sektionspraparaten von 19 Kindern im Alter bis zu 3 Jahren vorgenommen Messungen betreffs der Grosse und der Form des Sprungbeins wurden auf Filmen vorgenommen und mit entsprechenden Messungen an anatomischen Praparaten verglichen Der Unterschied zwischen den Ergebnissen und die Zuverlassigkeit der rontgenologischen Methode, anhand doppelter und dreifacher Untersuchungen, werden diskutiert

RÉSUMÉ

Les auteurs ont fait des arthrographies simultanees des articulations tibio tarsiennes et astragalo scaphoïdiennes sur 32 pieces anatomiques de pieds de 19 enfants jusqu a l age de 3 ans Des mesures concernant les dimensions et la forme de l astragale ont ete faites sur les films et les résultats ont eté compares avec les mesures correspondantes faites sur les pieces anatomiques Les auteurs examinent les differences entre ces resultats et la fiabilite de la methode radiographique analysee par des examens repétes en double et en triple

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NORMAL WIDTH OF CRANIAL SUTURES IN THE NEONATE AND INFANT

An objective method of assessment

U ERASMIE and H RINGERTZ

In the neonate and infant, radiologically demonstrated widening of the sutures is a generally appreciated and important sign of increased intracranial pressure As early as in 1946 HENDERSON & SHERMAN reported on variations of suture width of the newborn Later on BUTZLER et coll (1972) performed a similar investigation in infants up to 3 months of age Neither survey resulted in practical application Thus precise evaluation of the suture width has been hampered by the absence of a suitable method of assessment In clinical practice estimation has by large been subjective and entirely depending on experience

The aim of the present investigation was to devise a reliable and easily employable method to determine the cranial suture width based on objective measurements

Material and Method

The material comprised 64 girls and 86 boys in the age interval of 0 to 60 days after birth all but 13 were considered mature at delivery

Before review the patients were classified in 5 groups based upon the neurologic symptomatology (Table 1)

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Table 1

Neurologic symptoms and signs in the original material The mean and SD (within parenthesis) in the last 5 columns are based only upon the appraisable cases

Group	Neurologic symptoms and signs	Total No of cases	No not apprais able	Mean potential of app raisal	Mean age (days)	Skull height (mm)	Skull length (mm)	λ (mm)	Y (mm)
1	None	36	4	2 4	14 (16)	95 (6)	128 (9)	1 5 (1 2)	20 (7)
2	Probably none	65	4	2 2	19 (17)	98 (8)	131 (10)	2 0 (1 6)	24 (11)
3	Slight	27	1	1 8	12 (14)	96 (6)	127 (8)	2 6 (1 2)	25 (9)
4	Moderate	17	0	2 0	18 (14)	99 (8)	131 (9)	3 9 (2.3)	35 (15)
5	Marked	5	0	2 0	19 (16)	100 (6)	133 (11)	7 2 (5 3)	49 (31)

The radiography was performed on a Lysholm skull table with FFD of 90 cm No correction for magnification was made in the calculations The lateral film alone was used for the measurements

Both coronal sutures were assessed at levels located at approximately one third (C_1 and C_2) and two thirds (C_3 and C_4) of their course between the crown and the skull base (Fig 1) In the same manner the lambdoid sutures were estimated halfway between the calvarium and the base of the skull (L_1 and L_2) The sum of these six measurements, in the following denoted Y, was used as one of the parameters expressing suture width

Another parameter employed was the occurrence of a V-shape of the coronal



Fig 1 The sites of the measurements indicated on the lateral film of a child with increased intracranial pressure The projected course of the coronal suture is divided in 3 approximately equal parts and the lambdoid suture in 2

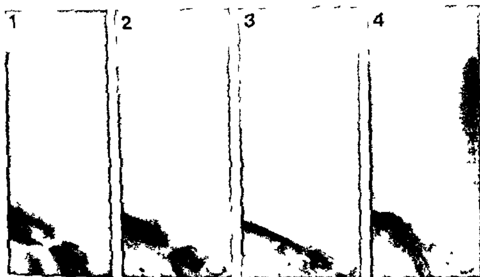


Fig. 2 Potential of appraisal as evaluated in 4 grades 1) is easily appraised 4) is not appraisable, 2) and 3) are intermediate

sutures that might ensue on widening of the suture This feature was expressed as the difference between the sums of top-near and basal measurements of the sutures $(C_1 + C_2)$ $(C_3 + C_4)$, and denoted X

In Table I the Y and X values of the cases are presented The relative potential of appraisal was evaluated in four grades (Fig 2) Cases belonging to grade 1 were easy to assess, while those belonging to grade 4 appeared unappraisable Nine of the original 150 cases belonged to grade 4 and were eliminated

In Fig 3 the Y and X values have been plotted in a diagram demonstrating the average and the ± 1 SD range A correlation between Y and X, in terms of increased suture width and V-shape of the coronal suture is well demonstrated Patients belonging to the clinical groups 4 and 5, e g those disclosing more or less evident neurologic abnormalities are deviating markedly from the rest of the material All 22 patients belonging to these two groups were excluded from the standard material as they were unsuitable for the purpose and probably abnormal

The age distribution in the remaining 128 patients is given in Table 2 It is evident that the mean values of Y and X tend to increase during the neonatal period, reaching a maximum between 15 and 30 days of age From then on the rates begin to decrease The Y and X values actually fall below the rates at birth 46 to 60 days after birth Therefore infants belonging to this latter age group were also excluded from the standard material The last prerequisite for cases to be accepted was a reasonably normal skull form and size The mean values for height and length of the vault as measured in 107 patients fulfilling these requirements appear in Table 1

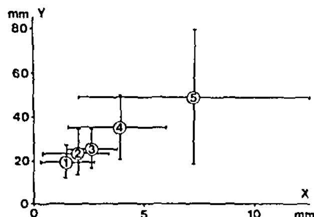


Fig 3 Diagram to demonstrate mean and ± 1 SD of X and Y for the five clinical groups

Results

In the standard material of 107 neonates between 0 and 45 days of age the mean and SD of X was found to be 2 1 ± 1 3 mm The corresponding figures for Y were 23 8 + 8 3 mm These values were used at construction of the diagram in Fig 4 The + 2 and + 3 SD curves were drawn to facilitate the assessment of borderline cases with possible widening of the cranial sutures Fig 5 constitutes a close-up of Fig 4 with the distribution of the standard material plotted into the diagram Four cases presented with values outside the + 3 SD and 11 cases outside the + 2 SD border From a statistical point of view this number of cases exceeds the expected rate, i e less than one case outside the + 3 SD border and between 2 and 3 cases outside the + 2 SD limit The application of the method in a normal case is demonstrated in Fig 6 In this case Y was equivalent to 15 mm and X to 3 mm

The upper extremes of vault length and height were 149 mm and 110 mm, respectively, among the finally selected 107 cases

Discussion and Conclusions

In neonates with increased intracranial pressure the circumference of the head may become augmented This feature depends either on a widening of the sutures, on

Table 2

Patients with none to slight neurologic symptoms and signs Mean and SD (within parenthesis) in the last 2 columns are based only upon the appraisable cases

Age (days)	Total No of cases	No not appraisable	Mean potential of appraisal	X (mm)	Y (mm)
0-7	55	2	1 8	1 8 (1 1)	21 (6)
8-14	23	0	1 7	2 5 (1 3)	24 (8)
15-30	25	4	2 5	2 8 (1 8)	32 (12)
31-45	11	1	2 5	1 9 (1 4)	22 (11)
46-60	14	2	2 9	0 9 (1 6)	16 (9)

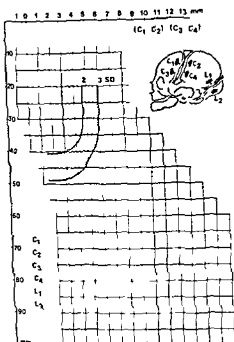


Fig 4

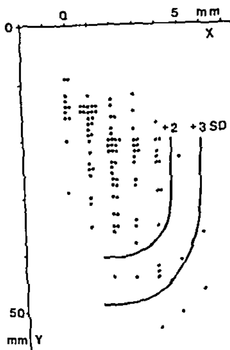


Fig 5

Fig 4 Upper normal limits for the proposed measurements of V-shape along the horizontal axis and sum of suture width along the vertical axis The dotted area represents values between 2 and 3 SD

Fig 5 The upper left part of the diagram in Fig 4 with the distribution of the 107 normal cases indicated

increased bone deposition in the suture margins or on both phenomena The degree of suture widening depends on three elements (a) age at onset of increasing intracranial pressure (b) duration of the condition, and (c) the speed at which the increment takes place (GOODING 1972)

Thus with slow or moderately rapid increase of the intracranial pressure, taking place over a fairly long period of time e g the situation prevailing in communicating hydrocephalus bone formation preponderates over suture widening This process results in an enlarged neurocranium with normal or slightly widened sutures In cases of this kind measurement of the skull circumference, and possibly the index of CRONQVIST (1968) may be considered more sensitive methods of appraisal than assessment of the suture width

By contrast, in non communicating hydrocephalus presenting with a faster increase in intracranial pressure bone formation will be slight and the widening of the sutures will dominate

The normal circumference of the neonatal skull is 352 ± 13 mm (SUNDAL 1957)



Fig 6 An example of the lateral view of a normal skull with X 3 mm and Y 15 mm

As calculated from the Y values in the present standard material, the part played by the two coronal and two lambdoid sutures seems to be 16+6 mm Consequently an increase in skull circumference from mean to +2 SD implies an increment in suture width from mean to +4 5 SD Thus, there will be a significant widening of the sutures before the increase in circumference of the neurocranium becomes obvious

Increased width of the sutures may occur also in other conditions than increased intracranial pressure Ossification anomalies and destruction of the bone along the sutures have been mentioned (STOKES & CREMIN 1974, SWISCHUK 1972, 1974) However, particularly the latter condition is extremely rare in the neonate

HENDERSON & SHERMAN, BUTZLER et coll, CAFFEY (1973), GOODING (1972) STOKES & CREMIN and others have presented methods to estimate the normal width of the sutures in neonates Although these methods certainly are dependable they have not found application in clinical routine

For the present purpose it was found most suitable to confine the appraisal to the width of both the coronal and lambdoid sutures and to the degree of V shape of the coronal suture STOKES & CREMIN have found the coronal suture to be the first to react on increased intracranial pressure, they also noticed the lateral view to be the most practical one for assessment The V-shape of the suture developing with increasing intracranial pressure depends on the relatively limited potential of diastasis at the skull base

The lateral view is easy to reproduce The sutures may be measured without difficulty if superimposed on each other and measurement is not rendered difficult if the projection is slightly oblique As a matter of fact an obliquity of up to 30° does not affect the accuracy of measurements and the resulting values The coronal suture is measured in a plane perpendicular to the beam and is thus insensitive to tilting The

lambdoid suture is measured at about 45° angle in the projection chosen Obliquity acts by increasing the width of the one suture while the dimension of the opposite one decreases correspondingly Thus the sum of the measured widths will not be influenced by obliquity of projection

In the sum of measurements constituting parameter Y, the coronal sutures have received twice the significance of the lambdoid ones Thus the relatively greater importance attached to the former sutures, in terms of more exact appraisement and greater sensitiveness, is enhanced

During the attempts to assemble a standard material of normal newborn skulls obvious problems were met with Of the originally collected 150 cases 43 were excluded (a) on clinical grounds, (b) as unsuitable in respect of age, and (c) as unappraisable The number of cases belonging to the clinical grades 4 and 5, primarily classified as within normal limits, but at review thought to be abnormal may appear surprisingly high However, this fact indicates the need of an objective method of evaluation The width of the sutures tend, as a rule, to increase during the first 2 to 4 weeks of life This depends upon the normal adjustment of the vault subsequent to moulding and fetal presentation (MOLOY 1942) In the period following the first month of life the trend changes to one of decreasing suture width Thus, at about 45 days after birth the absolute initial width starts to diminish This was one of the reasons why patients older than 45 days at the examination were excluded from the material Another reason was the decreasing accuracy of appraisal during the following weeks (Table 2), due to the mode of ossification of sutures near bone (BÜTZLER et coll)

The statistical distribution of the 107 cases, accepted for inclusion into the standard material, indicates a likely presence of abnormal cases in spite of the attempts to make a most careful selection Actually the curves of +2 SD and −3 SD in Figs 4 and 5 are somewhat shifted to the right, i e the true range probably would have been slightly more narrow in a strictly normal material However, the error is small and of no practical importance

Finally it has to be pointed out that application of Fig 4 should be reserved for skulls of a size within the range included in the standard material, i e a length of the cranium below 149 mm and a height below 110 mm measured radiographically With marked moulding deformity of the vault the method should be applied with caution

SUMMARY

A material of 107 normal skull films have been used to determine the normal range of the cranial sutures in the age group 0 to 45 days of age Assessment is based on the lateral view and includes evaluation of both coronal and lambdoid sutures as well as the degree of V shape of the coronal sutures Values obtained are easily classified as normal, borderline or pathologic by use of a simple diagram

ZUSAMMENFASSUNG

Eine Serie von 107 *normalen Schädelfilmen* wurde verwendet um die normalen Variationen der Schädelnähte in der *Altersgruppe von 0* bis 45 Tage zu bestimmen. Die Bestimmung wurde auf Seitenbildern vorgenommen und umfasst eine Untersuchung der Kranz und Lambdanähte sowie des Grades der V-Form der Kranznaht. Die erhaltenen Werte konnen leicht als *normal*, intermediar oder pathologisch mittels eines einfachen Diagrammes klassifiziert werden.

RÉSUMÉ

Les auteurs ont utilisé une série de 107 radiographies de crânes normaux pour déterminer les *variations normales* des sutures craniennes dans le groupe d'âge de 0 à 45 jours. Cette étude est basée sur la radiographie de profil et comprend l'examen des sutures coronales et lambdoïdes ainsi que le *degré de forme* en V des sutures coronales. Les valeurs obtenues sont aisément classées *en normales*, limites, ou pathologiques par l'utilisation d un simple diagramme.

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ANGIOGRAPHY OF OMENTAL CYSTS IN A CHILD

B JACOBSSON, G MELLGREN and G REUTERSKIÖLD

The increasing demands on precise diagnoses of expansive processes of the abdomen in children have resulted in a wider use of angiography (McDONALD & HILLER 1968, BRON et coll 1969, MOES & BURRINGTON 1971, CREMIN & KASCHULA 1972) A preoperative diagnosis and also the operative intervention are facilitated by angiography, because information of the topography of the vessels supplying the mass is obtained

Since omental cysts in children appear to be rare (MASON-BROWN 1962) and angiography has not been applied in this condition, the present case is reported

Case report

A 3 year old girl previously always well was first seen at the local hospital, because she was listless tired and irritable Clinical examination revealed no evidence of abnormality However at reexamination one week later the abdomen was enlarged and tender, although soft

A conventional film of the abdomen demonstrated a large tumour and the patient was therefore referred to the Department of Pediatric Surgery on the suggestion of Wilms' tumour

On admission her abdomen was symmetric in shape a soft lump with diffuse margins was palpable and mainly extended to the right of the midline

Submitted for publication 5 December 1975


a


b

Fig 1 Selective celiacography a) Early b) late arterial phase Gastroduodenal artery (→) is relatively wide and the omental branches are stretched and pushed apart The artery supplies several round poorly vascularised expansive lesions producing curved impressions in the intestines No abnormal vessels



Fig 2 The omental cysts at surgery

Conventional films of the abdomen An expansive lesion the size of a coconut, sited centrally in the abdominal cavity, displaced the intestines upwards and somewhat dorsally producing curved impressions No calcific deposits were present and no evidence of increased amount of fluid in the abdomen The psoas muscles were well outlined

Urography The lower renal poles were somewhat displaced, the right one laterally and the left one medially The kidneys, calyces and renal pelves were well outlined The ureters appeared to be slightly compressed at the level of the promontorium

Radiography thus suggested an intraperitoneal site of the tumour

Abdominal aortography and selective celiacography The gastroduodenal artery was abnormally wide and the omental branches were stretched (Fig 1) The omentum contained at least 6 round expansive lesions, 6 to 8 cm in diameter They were poorly vascularised but contrast medium accumulated in the walls No abnormal vessels or any shunting of the contrast medium were observed Angiography thus indicated multiple cysts of the omentum

Operation A conglomerate of cysts of the omentum extended from the greater curvature of the stomach into the small pelvis (Fig 2) The cysts were easy to dissect from the stomach and the omentum, which could be spared The entire growth was removed without disruption of the cysts

Microscopy demonstrated structures closely resembling cystic lymphangioma, no evidence of malignancy was found

Discussion

The present case report illustrates the value of angiography in the investigation of a child presenting with an abdominal tumour of undetermined origin Angiography certainly ruled out a Wilms' tumour which was the suggested diagnosis of referral

Most omental cysts are lymphangiomas, although sarcomas have also been described (MASON BROWN) In the present case angiography indicated that the tumour was benign, and microscopy that it was a lymphangioma Perusal of the literature revealed no case of omental cysts diagnosed angiographically Since, according to MASON BROWN, it is not possible on clinical evidence alone to distinguish between omental and mesenteric cysts, which sometimes require intestinal resection, the value of angiography in establishing the origin of the tumour is obvious

SUMMARY

Report of a case of preoperative angiographic diagnosis of omental cysts in a 3-year old child

ZUSAMMENFASSUNG

Bericht einer praoperativ angiographisch diagnostizierten Cyste des Omentum bei einem 3 jahrigen Kind

RESUME

Présentation d un cas de diagnostic angiographique pre operatoire de kyste du mesentère chez un enfant agè de 3 ans

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REACTION OF FEMORAL AND COMMON CAROTID ARTERIES IN INFANTS AFTER PUNCTURE OR PERCUTANEOUS CATHETERIZATION

K BERGSTRÖM and H JORULF

Abnormal arterial appearances following angiographic procedures in childhood have been reported by several authors (JACOBSSON et coll 1973, MORTENSSON et coll 1975 among others) However, only a few materials include infants The abnormal appearances or circulatory impairment were demonstrated in this age group by repeat angiography, oscillometry or confirmed at operation (REAL et coll 1966, WHITE et coll 1968 HOHN et coll 1969)

The femoral artery in rabbits with diameters comparable to those of newborn infants react with a high frequency of spasm on percutaneous puncture or catheterization while no reaction was demonstrated in the common carotid artery (BERGSTRÖM & JORULF 1976) Similar findings were reported by GÖTHLIN & OLIN (1970) following various mechanical injuries to the vessels

The aim of this investigation was to compare the immediate reaction of the femoral and common carotid arteries following percutaneous puncture or catheterization in infants

Material and Methods

The material comprised 34 infants of the age 0 to 12 months (mean 8 months) Transfemoral catheterization was performed in 16 infants and in 18 infants puncture

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(8 cases) or direct catheterization (10 cases) of the common carotid artery The indications for transfemoral catheterization were abdominal tumours in 6 cases and cerebral lesions in 10 cases

Angiographic technique All angiographies were performed percutaneously in general anaesthesia In femoral catheterization also periarterial local anaesthesia was used In these examinations and in those performed with puncture or direct catheterization of the common carotid artery in infants 0 to 6 months of age, the diameter of the puncture needle was 0 94 mm However, in the last 4 cases of femoral catheterization the diameter of the needle was 0 82 mm A polyethylene catheter (OD 0 97 mm, ID 0 63 mm) was used The diameter of the guide wire was 0 50 mm In infants 7 to 12 months of age, the diameter of the puncture needle was 1 08 mm the OD of the catheter was 1 22 mm and the ID 0 94 mm, the diameter of the guide wire being 0 61 mm After completion of the abdominal or cerebral angiography an injection was made into the lower abdominal aorta to compare the diameters of both femoral arteries After the puncture or direct catheterization of the common carotid artery, a lateral view of the artery was exposed In all cases one of the series also included the ipsi-lateral carotid artery

Results

The diameter of the femoral artery on the non-catheterized side was 2 0 to 4 1 mm (mean 2 7 mm) and of the punctured or catheterized common carotid artery 4 3 to 6 2 mm (mean 5 4 mm)

The femoral artery The degree of spasm was registered as follows slight spasm (diameter reduced 1/3), moderate spasm (diameter reduced 1/3 to 2/3), marked spasm (diameter reduced more than 2/3) In all examinations except one, spasm or arrested flow were recorded Slight spasm was registered in 2 cases, moderate in 2 marked in 4 and arrested flow in 7 cases In 5 of the cases with arrested flow, the external iliac artery was also involved and in 2 cases even the common iliac artery

The common carotid artery No spasm or other acute abnormalities of the common carotid artery were observed

Discussion and Conclusions

The investigation demonstrated a marked difference in reaction between the femoral and common carotid arteries in infants to mechanical trauma at puncture or catheterization This agrees with the findings in rabbits (GOTHLIN & OLIN 1970, BERGSTRÖM & JORULF 1976)

In previous reports of the abnormalities of the femoral artery elicited by puncture

or catheterization a higher rate was registered in younger than in older children (cf MORTENSSON et coll 1975) These authors reported thrombotic occlusion of the artery in 5 per cent in children aged 2 to 16 years, mainly in the young children The high frequency of spasm or arrested flow of the femoral artery in infants demonstrated in the present material supports the theory that the risk for persistent occlusion is even higher in infants than in young children Transfemoral catheterization in infants invariably should be completed with a film of the catheterized artery During and after the angiographic procedure the artery flow can be continuously controlled by ultrasound according to the Doppler method (BERGSTRÖM & JORULF, to be published)

By contrast the common carotid artery is very resistant to spasm also in infants However, both the internal and external carotid arteries tend to react with spasm at increasing frequency the more peripheral to the carotid bifurcation the catheter tip is placed

In view of the sensitivity of the infant femoral artery to trauma, restriction to only one puncture during the catheterization procedure of the artery is recommended To minimize the trauma it is important to use thin-walled needles and catheters with as small a diameter as possible In unilateral carotid angiography transcarotid catheterization is preferred to the transfemoral approach

SUMMARY

In infants, the femoral artery reacts with spasm or arrested flow in a high frequency after catheterization By contrast, the common carotid artery is very insensitive to puncture or direct catheterization

ZUSAMMENFASSUNG

Bei Kindern reagiert die A femoralis in einer hohen Frequenz mit Spasmen oder einem unterbrochenem Blutstrom nach einer Katheterisierung Im Gegensatz dazu ist die A carotis communis sehr unempfindlich gegenuber einer Punktierung oder einer direkten Katheterisierung

RÉSUME

Chez les nourrissons, l artere femorale reagit tres souvent par un spasme ou par un arret du débit après cathétcrisme Au contraire, l artère carotide primitive est tres peu sensible a la ponction ou au catheterisme direct

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ANGIOGRAPHY OF THE FEMORAL ARTERY FOLLOWING PERCUTANEOUS CATHETERIZATION IN INFANTS AND CHILDREN

W MORTENSSON

Percutaneous catheterization of the femoral artery in children is reported to have caused thrombotic complications in the catheterized artery in up to 37 per cent of the cases The great range in frequency may be attributed to the varying composition of the clinical material, the various procedures used at catheterization and at control examination, and to the definitions of thrombotic complications

Different factors have been considered as contributing to the development of thrombosis Thus, in recent years interest has been focused to a great extent on the significance of the thrombogenic properties of the catheter The coating of thrombocyte clots, which appears on the catheter surface and which is wiped off on withdrawal of the catheter, has been said to be the source of thrombosis (NEJAD et coll 1968, JACOBSSON 1969, JACOBSSON et coll 1969, JACOBSSON & SCHLOSSMAN 1969, ELDH 1973) Other authors have regarded mechanical injury to the arterial endothelium as the primary factor initiating thrombosis (HALPERN 1964, IZUKAWA et coll 1968, FELLOWS 1972, HALL 1971) This hypothesis was also supported by previous measurements of blood flow to the calf muscles before and after percutaneous catheterization of the femoral artery (MORTENSSON et coll 1975 b)

Angiography of the femoral arteries, previously catheterized percutaneously, was performed in order to evaluate the appearance, extent, and frequency of thrombotic

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Table 1

Distribution of 50 percutaneous catheterizations of the femoral artery according to type of catheterization, diagnosis and age of patient at primary catheterization

	Group I 0 to 8 years	Group II 8 to 16 years
Cardiac catheterization		
Aortic stenosis	4	4
Cyanotic heart disease with haematocrit ≥44 per cent	15	1
(Thereof Fallot's anomaly)	(6)	(0)
Remaining types of heart disease	13	9
Selective catheterization of abdominal or pelvic arteries		
Renal or adrenal tumours	2	0
Vascular malformation in the lower extremity	0	2
Total number of catheterizations	34	16

complications and to determine the conditions which may be contributory to such complications (Preliminary experiences were reported by MORTENSSON at the 11th Annual Meeting of the European Society of Paediatric Radiology in 1974.)

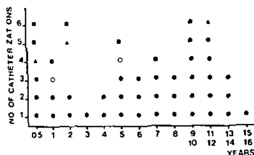
Material and Methods

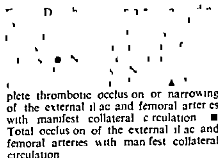
The material comprised 44 infants and children who were subjected to repeat catheterizations via the femoral arteries. All of the catheterizations were performed on strict medical indications. All but 3 patients had heart disease and had undergone cardiac catheterization including pressure recording, blood sampling and cardioangiography (Table 1). The ages of the patients at the time of catheterization appear in Fig. 1.

Previous experiences had shown that the following conditions may involve increased risk of thrombosis of the artery: low age of the patient, increased haematocrit value, repeated catheter manipulations which may be necessary to pass the catheter from the aorta to the left ventricle in cases with aortic valve stenosis, or to both the left and right ventricles in cases of Fallot's anomaly. These conditions were therefore considered in the classification of the patients (Table 1).

The right and left femoral arteries were used alternatively at the repeat catheterization of the individual patients and at the same time angiography of the femoral and iliac arteries was performed to determine the condition of the vessels previously catheterized. Five patients were catheterized more than twice. The effect of the catheterization could thus be analysed after a total of 50 catheterizations in 44 infants.

The catheterization technique included percutaneous insertion of the catheter under local anaesthesia without vasoconstrictive agents. Polyethylene catheters,





which had been stored in a benzalkonium solution were used and were flushed at intervals with heparin saline The total amount of heparin given to each patient varied between 250 and 750 IU but was not measured in every case (For further details on the catheterization procedure see MORTENSSON et coll 1975 a)

The primary catheterizations were performed during the period 1965 to 1973 and the repeat angiographies in 1969 to 1975 The time lapse between primary and repeat catheterization varied between 2 months and 9 years (mean interval 3 1 years) The material was divided into two groups group I consisting of children less than 8 years old at primary catheterization group II of children between 8 and 16 years

Results

Normal conditions were encountered in 37 cases Complete arterial occlusion was found in 6 cases (Fig 2) and in 5 of these it extended from the beginning of the external iliac artery distally to the site of the previous catheter insertion Collateral circulation was established through the obturator artery and circumflex arteries branching from the internal iliac and femoral arteries respectively in 2 cases in addition via the gluteal arteries In the remaining case the thrombotic occlusion also involved the common iliac artery and the collateral circulation was built up by anastomoses from the mesenteric and contralateral internal iliac arteries to the ipsilateral internal iliac artery From this latter artery connections existed to the femoral artery

Incomplete arterial occlusion with manifest collateral circulation existed in 3 cases (Figs 3 4) In these cases the mural changes were located at various sites in the external iliac artery and the proximal part of the femoral artery The entire external iliac artery was slightly narrowed in one of the cases and in another it was markedly narrowed (Fig 4) Collateral circulation was established between the ipsilateral internal iliac artery and the femoral artery

Small mural abnormalities were demonstrated in 4 cases and were of two types one type (3 cases) was discrete and distributed along the external iliac artery and proximal part of the femoral artery the other type was stellate clearly delineated



Fig 2 Complete thrombotic occlusion of external iliac artery and proximal part of femoral artery down to site of catheter insertion 52 months previously Abundant collateral vessels connecting iliac and femoral arteries

Table 2

Frequency of pathologic findings in previously catheterized arteries related to the age of the patient at primary catheterization Group B Minimal mural abnormalities no or possibly discrete collateral circulation Group C Incomplete thrombotic occlusion or narrowing of the external iliac and femoral arteries with manifest collateral circulation Group D Total occlusion of the external iliac and femoral arteries with manifest collateral circulation n number of catheterizations

	Group B	Group C	Group D	Groups C + D	Groups B + C + D
I 0 to 8 years n = 34	12 %	6 %	18 %	24 %	35 %
II 8 to 16 years n = 16	0 %	6 %	0 %	6 %	6 %
Total n = 50	8 %	6 %	12 %	18 %	26 %



Fig 3





Fig 4

Fig 3 Incomplete occlusion of proximal part of femoral artery and mural abnormalities also distally in external iliac artery Catheter insertion into femoral artery 26 months previously Extensive collateral circulation Symptoms of claudication upon effort

Fig 4 On the left side, entire external iliac artery and proximal part of femoral artery narrow, a few small mural abnormalities Catheter insertion through left femoral artery 47 months previously

and confined to the site of the previous puncture and catheter insertion (Fig 5) The pudendal branch of the femoral artery was somewhat wide in 2 cases, the direction of the blood flow in these branches could not be established No or only discrete collateral circulation existed in the cases with small abnormalities only

The distal pulses of the leg were weak or absent in one patient after completion of the catheterization and the leg was cyanotic although warm Otherwise thrombotic complications were not suggested in any patient in the catheterization reports

The pathologic vascular lesions were found almost exclusively in group I ($0.1 > p > 0.05$ Fig 1, Table 2) Group II included only one case with arterial abnormality incomplete thrombotic occlusion of the femoral and external iliac arteries were present in an 11-year old girl with aortic valve stenosis (Fig 3) This age group is therefore not included in the statistical evaluation of the significance of certain conditions in the occurrence of thrombotic complications

The incidence of post-catheterization lesions—irrespective of type—was not found to be higher in patients with aortic stenosis or Fallot's anomaly (Fisher's exact test for the four fold table) or in patients with increased heamatocrit value (> 44 per cent)



Fig 5 Stellate lesions (→) at site of catheter insertion 14 months previously Widespread discrete mural changes in external iliac artery

at the time of the primary catheterization (Fisher's test, Wilcoxon's rank sum test) than in the remaining cases (Table 3) In 2 patients with uncomplicated angiography the haematocrit value was not determined This value would reasonably fall within the normal range, and could not in any case have influenced the result of the statistical calculations

The tendency to spasm in the arteries used for catheter insertion was investigated

Table 3

Findings related to diagnosis at 34 repeat angiographies All patients were 8 years or younger at primary catheterization Group A Normal condition (For explanation of groups B C and D, see Table 2) n number of catheterizations

	Groups				n
	A	B	C	D	
Aortic stenosis	3	0	0	1	4
Cyanotic heart disease	8	3	1	3	15
(Fallot's anomaly)	(3)	(2)	(0)	(1)	(6)
Remaining heart diseases	10	0	1	2	13
Retroperitoneal tumours	1	1	0	0	2
Total	22	4	2	6	34



Fig 6 Catheter (→) inserted percutaneously into left femoral artery Catheter manipulations evoke maximum spasm of external iliac artery and proximal part of femoral artery Preexisting anastomosis between the internal iliac and femoral arteries is dilated, ensuring blood flow to the femoral artery

in 45 of the repeat angiographies Maximum vascular spasm with obliteration of the lumen around the catheter (Fig 6) was frequent in the youngest patients and involved the entire external iliac artery and the proximal part of the femoral artery (Table 4) In children older than 8 years at the time of repeat catheterization, it occurred only once, namely in the patient who at 11 years of age had incomplete

Table 4

Vascular spasm in the external iliac artery and in proximal part ...
insertion at repeat catheterization at ...
ing of the femoral artery at site of ...
in width of external iliac artery and proximal part of femoral artery 3 – Maximum spasm in external iliac artery and proximal part of femoral artery, with no visible vascular lumen around the catheter
n number of catheterizations

Age of patient at repeat catheterization	Angiographic findings				n
	0	1	2	3	
> 8 years	18	2	2	1	23
6 to 8 years	0	3	1	2	6
3 to 5 years	4	0	4	4	12
0 to 2 years	0	0	0	4	4
Total					45

Table 5

Previous determinations of arterial blood flow to the leg after ipsilateral percutaneous catheterization of the femoral artery With few exceptions catheterization was performed because of heart disease

Reference	Number of cathet	Age of patients	Repeat examination: Method	Repeat examination: Time	Findings	Per cent
HOHN et coll (1969)	8	1 year	Oscillometry	one day post cathet	Diminished oscillations	37
	67	1 to 18 years	Oscillometry	one day post cathet	Diminished oscillations	9
BERMAN et coll (1972)	20	?	Oscillometry	one day post cathet	Normal in all cases	
JACOBSSON et coll (1973)	33	6 months to 13 years	Oscillometry*	yrs post cathet	Diminished oscillations*	36
FREED et coll (1974)	84	10 to 16 years	Oscillometry	one day post cathet	Normal in all cases	
MORTENSSON et coll (1975 b)	46	2 to 8 years	Plethysmography	day of and one day post cathet	Thrombotic occlusion	11
		9 to 16 years	Plethysmography	day of and one day post cathet	Normal in all cases	

* Angiography was performed in 5 and plethysmography in 8 children with pathologic oscillometry, thrombosis and reduced flow, respectively, were demonstrated in these patients

thrombotic occlusion after catheterization During such maximum arterial spasm, blood flow to the leg was ensured by dilatation of preexisting anastomoses connecting the internal iliac and the femoral arteries Slight or moderate spasm in the external iliac artery and the proximal part of the femoral artery was also more common in younger than in older children (Table 4) The incidence of arterial spasm in the catheterized arteries was significantly higher in children belonging to group I than in the older children (p 0 002, Fisher's test)

The time lapse between insertion and withdrawal of the catheter was reported in 31 of the 34 primary catheterizations in group I It varied between 10 min and 2 h 45 min (mean value 1 h 23 min), the means were 5 to 20 min longer for the various groups with post-catheterization thrombosis than for the group of uncomplicated cases However, no significant difference was found between the mean catheterization time for children with uncomplicated catheterization and that for children with various types of thrombotic complications (Student's t-test) The mean catheterization time for group II was 58 min, which did not differ significantly from that for group I

Discussion

The frequency of thrombotic complications in children following percutaneous catheterization of the femoral artery appears in Table 5 Only those examinations are included which were based on recording of the circulation in the leg It must be

pointed out that the results of the various examination methods are not fully comparable, e g, the small mural lesions (Fig 5) had certainly not been possible to register at oscillometry or plethysmography Furthermore, the degree, extent, and location of the thrombotic (or embolic) lesions are not always clearly expressed in the reports Angiography is without doubt the best method to demonstrate thrombotic vascular abnormalities, in animal experiments a good agreement was found between angiographic abnormalities and postmortem findings (CRNIC et coll 1973) Excluding the cases with minimal mural lesions and taking the age distribution into consideration, the frequency of thrombotic complications in the femoral and external iliac arteries in the present material was equal to or somewhat higher than the rate reported by HOHN et coll (1969), FREED et coll (1974) and MORTENSSON et coll (1975 b) The material by JACOBSSON et coll (1973) consisted of selected cases which were considered to have run a considerable risk of catheterization complications (' examined with catheters of considerable length and outer diameter and made of relatively thrombogenic material), thus, their report is less suitable for frequency analysis BERMAN et coll (1972) reported a low incidence of thrombotic complication but unfortunately the ages of the patients were not given

In the present material, age at catheterization was the only factor, which was found to be related to the occurrence of thrombotic complications in the catheterized arteries

Arterial spasm during and thrombotic lesions following catheterization occurred almost exclusively in the infants and young children In addition, both conditions usually affected the same arterial segments The risk of endothelial injury is obvious at repeated catheter manipulations in a narrow and contracted vessel and the intima becomes highly thrombogenic at sites where the endothelium is injured (MUSTARD et coll 1974, BAUMGARTNER 1974) Actually even the slight trauma produced by the hooked catheter tip sliding against the aortic wall was found in dogs to produce mural thrombosis (VAN DE WEYER et coll 1970)

The present results strongly support the conception that thrombotic complications in the catheterized arteries are secondary to mechanical injuries to the intima The evocation of arterial spasm at catheterization of young children, and the significance of this spasm for the occurrence of thrombotic complications has been reported previously (IZUKAWA et coll 1968, CONVERT 1972, MORTENSSON et coll 1975 b, BERGSTRÖM & JORULF 1975) This mechanism may also be responsible for thrombotic occlusion of the femoral artery in adults, as is strongly suggested by ERIKSSON & JORULF (1970, Fig 1)

Various disturbances of the clotting mechanism, such as increased platelet adhesiveness and aggregation, have been reported in children with cyanotic heart disease (GOLDSCHMIDT 1974) It would therefore [illegible]

[illegible] with increased haematocrit value in group I

may be the result of a skew age distribution: a large number of the polycythaemic patients were less than 2 years old at primary catheterization

A wide range of the catheterization time existed in uncomplicated as well as complicated procedures Absence of correlation between the time and the occurrence of thrombotic complications is concordant with previous reports (KIRKPATRICK et coll 1970, FELLOWS 1972, JACOBSSON et coll 1973, FREED et coll 1974, MORTENSSON et coll 1975 b) It should be pointed out that the length of the catheterization time depends mainly on the time consumed in carrying out concurrent procedures such as pressure recording and performance of angiography, during which the catheter is left in position

In the acute stage of the occlusion of the artery following catheterization, signs of impaired circulation may be discrete in children as well as in adults, and may easily be overlooked (adults FOGARTY & KRIPPAEHNE 1965, MORTENSSON 1967, BOUHOUTSOS & MORRIS 1973, BARNES et coll 1974, children CAHILL et coll 1967, JACOBSSON et coll 1973, BLOOM et coll 1974, MORTENSSON et coll 1975 b) Tissue loss is extremely rare in children These circumstances, which are also confirmed in the present material, may explain the very low frequency of complications (less than 3 per cent) in reports without use of objective registration methods (MORTENSSON et coll 1975 b) At thrombotic occlusion preexisting communications between the internal iliac and the femoral arteries are probably immediately widened, as may be demonstrated in cases of intense vascular spasm, thus, blood flow to the extremity is ensured (Fig 6) This was also observed following acute occlusion of the femoral artery in animal experiments (BRKIC & LASZT 1973) The arterial resting flow to the leg, recorded in the calf, was normal in the acute stage of femoral occlusion, however, arterial peak flow was substantially reduced (MORTENSSON et coll 1975 b) At a later stage, the arterial peak flow may be normal in spite of complete arterial occlusion, which may be ascribed to the collateral circulation (personal observation) However, arterial peak flow is probably reduced at this stage in most of the cases as reported by JACOBSSON et coll (1973)

Acute occlusion of the femoral artery may influence the growth of the affected extremity Reports have appeared in the literature on series or single cases of retarded growth of the leg and atrophy of skin and muscles (BASSETT et coll 1968, WHITE et coll 1968, TAKAHASHI et coll 1970, HAWKER et coll 1973, JACOBSSON et coll 1973, BLOOM et coll 1974) Unequal length of the legs was encountered in at least 4 of the patients with total occlusion, the leg on the catheterized side being 6 to 20 mm shorter than the other at measurements 4 to 7 years after the primary catheterization Symptoms were present in one patient, the 13-year-old girl who had claudication upon effort

Absence of collateral circulation in the 4 cases with small lesions suggests, as could be expected, that these abnormalities had no haemodynamic effect However, it remains to be seen whether or not these slight mural injuries will give rise to precocious appearance of local atherosclerotic lesions

SUMMARY

Iliac and femoral arteries previously exposed to percutaneous catheterization were examined by angiography in conjunction with re-catheterization in 44 infants and children, most of them with heart disease Frequency and extension of thrombotic changes were analysed, as well as the relationship between occurrence of thrombotic complications and age, haematocrit value, catheterization time, and tendency to arterial spasm Only age and arterial spasm were significant for the occurrence of thrombotic complications Injury of the intima was considered to be the primary cause of these complications

ZUSAMMENFASSUNG

Die Arterien des Beckens und Femurs, die fruher einer perkutanen Katheterisierung ausgesetzt worden waren, wurden im Zusammenhang mit einer erneuten Katheteruntersuchung von 44 Sanglingen und Kindern, die meisten mit einer Herzerkrankung, durch Angiographie untersucht Frequenz und Ausmass thrombotischer Veranderungen wurden ebenso wie die Beziehung zwischen dem Vorkommen von thrombotischen Komplikationen und dem Alter, dem Haematokritwert, der Katheterisierungsdauer und der Tendenz fur arterielle Spasmen untersucht Nur das Alter und der arterielle Spasmus waren signifikant fur das Vorkommen thrombotischer Komplikationen Ein Schaden der Intima wird als primare Ursache dieser Komplikationen angesehen

RÉSUMÉ

Des artères iliaques et fémorales
ont été exar
et enfants
quence et l'étendue des modifications thrombotiques ainsi que la relation entre l'apparition
de complications thrombot
et la tendance aux
dans l'apparition des
l'intima est la cause ... de ces complications

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INFANTILE CORTICAL HYPEROSTOSIS

Report of a case with late manifestation

I CLAESSON

Although the pathogenesis of infantile cortical hyperostosis, or Caffey's disease, is still obscure, its clinical course and radiologic appearance are well defined Since the first account of this entity by CAFFEY & SILVERMAN (1945) numerous cases have been reported all attesting to the fact that there are only small variations in the clinical symptomatology and the distribution of the skeletal manifestations The time of onset of the disease is early and has never been reported to be later than the 5th month of life This report presents a case with a classical clinical and radiologic appearance of infantile cortical hyperostosis, although its strictly defined onset was as late as 4 5 years

Case report

The patient, male, white, was born after 32 weeks gestation time He was nursed for some months at the hospital and because Hurler's syndrome was suggested, radiography of the chest, extremities, head and spine was performed No abnormalities were found He was discharged home in a good clinical state

At the age of 4 years and 7 months a sudden onset of disease occurred with general irritability, fever and localized hard swelling and tenderness over the anterior middle part of left lower leg with no evidence of previous infection No local increased heat or discoloration of the skin was present One week later ESR was 43 mm/h and there was a slight leucocytosis Radiography of the left lower leg revealed periosteal new bone formation and oedema of the perifocal tissue

The disease was considered to be osteomyelitis and antibiotic therapy was instituted One week later the patient complained of pains in the right lower arm and radiography demonstrated changes in the shaft of the ulna similar to those observed in the left tibia After a further 3 weeks of antibiotic therapy an antiphlogistic remedy was added resulting

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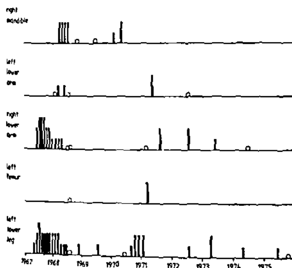


Fig 1 Skeletal involvement during the course of juvenile cortical hyperostosis O = no evidence of new bone formation ıǀǀ = slight, moderate and marked radiographic abnormalities

in a marked effect on the swelling and tenderness In spite of this clinical improvement, the ESR [illegible]
skeletal [illegible]
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Markec [illegible] in this condition with pain in the left leg became again apparent. As the skeletal abnormalities seemed to be identical with those described in infantile cortical hyperostosis, treatment with corticosteroids was instituted A prompt clinical response occurred with an immediate reduction in ESR and an increase in the haemoglobin level The corticosteroid therapy was gradually withdrawn

In the ensuing 5 years the patient experienced repeat episodes of local exacerbations and remissions during which corticosteroids have been administered for short periods always with prompt relief of the symptoms The time of appearance of the skeletal [illegible]

[illegible] there was a slight to moderate [illegible]emia with a lowest [illegible] and 4 200/mm³ with [illegible]t was normal One [illegible] from the sternum [illegible] normal on repeat [illegible] tests were negative and so were several urine analyses

Three biopsies from the left tibia were taken on different occasions The first two biopsies contained cortical bone and small fragments of medullary bone There was evidence of chronic inflammation with increased amounts of fibrous tissue and inflammatory cells, mostly lymphocytes The third biopsy specimen consisted of cortical and medullary bone with a rim of newly formed bone on the surface of the cortex, and revealed increased formation of fibrous tissue in the medullary cavity with lymphocytes



Fig 2 One week after clinical onset Periosteal new bone formation of the left tibia along the diaphysis and perifocal soft tissue swelling



Fig 3 Six weeks after onset Excessive amounts of periosteal new bone along tibia and fibula

Radiologic appearances

Left lower leg At the first examination after onset of the clinical symptoms swelling and oedema of the soft tissue surrounding the diaphysis of the tibia was demonstrated (Fig 2) Cortical thickening and periosteal new bone formation along the diaphysis was also found Ten days later the bone deposition had increased considerably and was even more marked 2 weeks later (Fig 3) The new bone formation had by then reached its maximum extent but some regression of the soft tissue changes was observed During the following 6 months the cortex was thickened while the periosteal changes became less and less marked Nine months after onset of the disease several interosseous bridges had formed between the tibia and fibula (Fig 4) the left tibia



Fig. 4 35 weeks after onset Bony bridges between tibia and fibula (—›) Considerable resorption of periosteal new bone The affected left tibia is 2.3 cm longer than the right one

Fig 5 Eight years and 10 weeks after onset No actual complaints Widening of the medullary cavity

Fig 6 Right lower arm Three weeks after local onset of disease Extensive new bone formation of ulna and moderate formation along radius Marked soft tissue oedema

was 2 3 cm longer than the right one In addition a slight bowing of the tibia could now be demonstrated One year after onset of the disease no periosteal changes were apparent but later new periosteal bone formation was observed several times concurrently with periods of clinical deterioration The last radiography of the left lower leg was performed 8 years and 10 weeks after onset of the disease (Fig 5)

Right lower arm The skeletal abnormalities were also closely followed with repeat radiography They were identical with those observed in the left lower leg (Fig 6)

Left lower arm The radiographic abnormalities ran an almost identical course The first examination was made for comparison on examination of the right lower

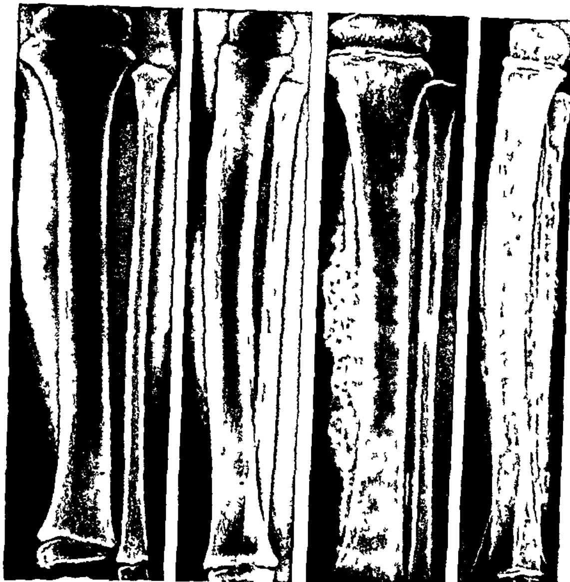


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Fig 7 Right mandible Eight weeks after local clinical onset Periosteal new bone formation (▲)

arm at a time when the patient had no clinical symptoms from the left lower arm, no skeletal abnormalities were apparent One month later a slight tissue oedema was observed and the sequence of events was the same as those met with in the right lower arm

Left femur On one single occasion the patient had symptoms from the left thigh typical changes with formation of new bone in the previously unaffected femoral shaft were observed

Mandible and skull Radiography was performed because of tenderness and swelling and revealed soft tissue oedema and periosteal new bone formation along the right corpus mandibulae (Fig 7)

Chest There was no evidence of involvement of the ribs on examinations of the thorax

Discussion

The clinical history, the laboratory and radiographic findings as well as the prompt effect of corticosteroid therapy all point to a diagnosis of Caffey's disease in the case reported Concerning the age of onset in infantile cortical hyperostosis, CAFFEY emphasizes 'there are no valid cases in which the onset has occurred later than the 5th month of life'

The present case obviously had a well defined onset of the disease at an age of 4 years and 7 months Purely by chance he happened to have undergone a fairly extensive radiography of the skeleton at the age of one month, the skeleton of the extremities and the mandible were without visible abnormalities at that time It is only remotely possible that skeletal manifestations of infantile cortical hyperostosis without clinical symptoms might have developed in this carefully supervised patient before the age of 6 months In addition the manifestation of the disease in the left lower

arm must have appeared after the age of 4 years 9 months and no skeletal abnormalities could be observed at that time when films were taken for the purpose of comparison

Initially the disease was considered as osteomyelitis Different antibiotics were used, sometimes in large doses and for long periods However, no unequivocal improvement during the course of the therapy was noted Once corticosteroids became instituted a dramatic effect followed The extent of new bone deposition was strictly limited to the diaphyses of the affected bones, neither the metaphyses nor the epiphyses were ever involved The limitation of involvement to the ulna, radius, tibia, fibula, femur and mandible is typical of infantile cortical hyperostosis and makes osteitis a less probable diagnosis similarly the prompt effect of corticosteroids is not in keeping with osteitis Repeat blood and tissue cultures have always been negative Biopsies revealed increased amounts of fibrous tissue, inflammatory cells and a rim of newly formed bone on the cortical surface These rather nonspecific findings may be encountered in osteitis as well as in infantile cortical hyperostosis The nonsuppurative osteomyelitis of Garre is almost invariably localized to one single bone and is easily ruled out (MESCHAN 1966)

Other diseases involving the cortex of long tubular bones during childhood like rickets, vitamin A intoxication, hyperphosphatasaemia and heavy metal poisoning all have symmetric distribution of skeletal involvement and usually manifest themselves during infancy In these entities the entire shaft of the tubular bones is involved It is true that in hypertrophic pulmonary osteoarthropathy the metaphyses are usually not involved similar to infantile cortical hyperostosis but the distribution of periosteal bone is different in that it is symmetric in the former In the Camurati–Engelmann s disease cortical thickening of the tubular bones of the extremities occurs, which also is limited to the diaphyses However, cortical involvement is both external and internal, and the thick cortex partly encroaches upon the medullary cavity A coexisting muscular weakness results in an almost pathognomonic waddling gait in this entity (CAFFEY 1973, SPRANGER et coll 1974) Tuberculous as well as syphilitic bony changes were excluded by laboratory and serological tests, and also by the remission following corticosteroid therapy

GOLDBLOM et coll (1966) described 2 children, aged 10 and 14 years, with cortical thickening of the long tubular bones and of the mandible These patients presented after a previous upper respiratory tract infection with fever and localized tenderness over both ulnae tibiae and mandible They also had [illegible]

[illegible] than in the present case The bony changes disappeared without any visible sequelae, while an overgrowth, a slightly increased cortical width and bony bridges were persistent findings in the present case

Late recurrence of infantile cortical hyperostosis has been described by SWERDLOFF et coll (1970) in 2 patients aged 12 and 15 years, who had well documented lesions in infancy Preserved films of the present case reject the possibility of early skeletal involvement

On the basis of these considerations, it is reasonable to denominate the condition of the present case as juvenile cortical hyperostosis

SUMMARY

Infantile cortical hyperostosis in a child with onset as late as 4 5 years of age although with an otherwise classical history and typical appearances on radiography is reported It is suggested that the condition should be classified as juvenile cortical hyperostosis

ZUSAMMENFASSUNG

Ein Kind mit infantiler kortikaler Hyperostosis, die erst bei 4,5 Jahren auftrat, aber so wohl klinisch als rontgenologisch ein typisches Krankheitsbild aufwies, wird beschrieben Es wird vorgeschlagen, die Krankheit juvenile kortikale Hyperostosis zu nennen

RÉSUMÉ

Presentation d un cas d hyperostose corticale infantile à début tardif, chez un enfant âgé de 4 ans et demi, alors que l histoire clinique est par ailleurs classique et que les aspects radiographiques sont typiques L'auteur suggere que cette affection soit classée comme une hyperostose corticale juvénile

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KIDNEY SIZE AND GROWTH IN UNILATERAL RENAL AGENESIS AND IN THE REMAINING KIDNEY FOLLOWING NEPHRECTOMY FOR WILMS' TUMOR

O EKLÖF and H RINGERTZ

In unilateral renal agenesis, and secondary to nephrectomy, the single functioning kidney almost invariably appears enlarged Only few attempts have been made to analyse in detail the growth cycle of the kidney and to determine its future size

LAUFER & GRISCOM (1971), considering multicystic dysplasia an equivalent to unilateral fetal nephrectomy, investigated a series of 40 pediatric patients with this anomaly They found a compensatory capacity for kidney growth during early infancy sufficient to make the total renal mass approximately normal by the age of 1 1 2 years The growth of the remaining kidney after the removal of its partner has been measured using rats (MALT 1969, KARP et coll 1971, GALLA et coll 1974, and others) Analysis of the results suggests that the response to uninephrectomy is an age dependent phenomenon

In human beings biochemical investigations indicate that up to 6 months of age increase *in kidney* size is mainly due to hyperplasia Subsequent renal growth is due to hypertrophy rather than to increase in cell number (BARRATT 1974) In analogy to the findings obtained in animal experiments some authors have suggested that compensatory growth may decelerate with advancing age (OGDEN 1967) Thus, in late adulthood little or no enlargement would be possible (HEIDEMAN & ROSENBAUM 1970) However, the validity of this statement seems doubtful, BONER et coll

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RESUMÉ

Presentation d un cas d'hyperostose corticale infantile à début tardif, chez un enfant agé de 4 ans et demi, alors que l histoire clinique est par ailleurs classique et que les aspects radiographiques sont typiques L'auteur suggère que cette affection soit classée comme une hyperostose corticale juvénile

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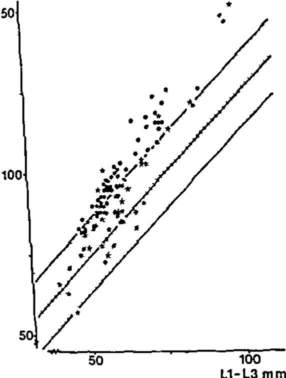


Fig 2 Preoperative renal lengths (stars) and lengths of 35 remaining kidneys following nephrectomy for Wilms' tumor, as measured on 106 urographies, plotted on same diagram.

RINGERTZ as a primary reference and a series of unilateral renal agenesis as a secondary reference An additional purpose was to demonstrate any potential influence of age, after the 'loss' of one kidney, on the growth of its partner

Material and Method

The material contained 11 girls and 13 boys with unilateral renal agenesis The mean age at diagnosis was 4 years, the median age 3 4 years The diagnosis was primarily established at urography, and subsequently confirmed either at nephro-angiography or cystoscopy, or by both procedures There was a somewhat higher incidence of agenesis on the left side A total of 48 urographies formed the basis of the evaluation Twenty-two patients were examined at 6 months of age or later, 11 of them at over 5 years of age

Wilms' tumor formed the major part of the material, comprising 22 girls and 13 boys, all of them uninephrectomized The mean age at operation was 3 4 years, the median age 2.4 years The right kidney was somewhat more frequently afflicted by

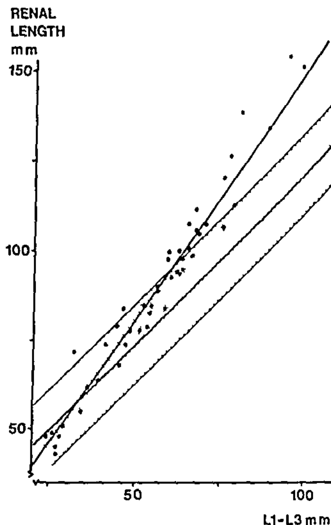
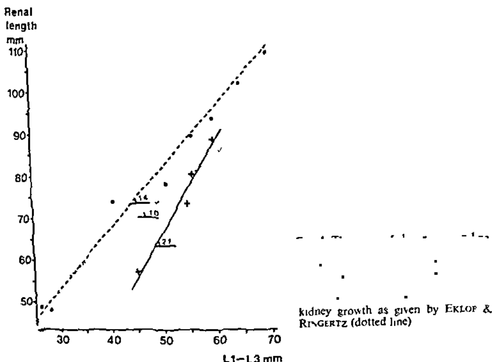


Fig 1 Length of kidneys determined from 48 urographies (dots) and regression line of kidney growth in 24 patients with unilateral renal agenesis, plotted on a diagram showing the regression line and range of kidney growth in the normal material of EKLÖF & RINGERTZ

(1972) and ROCKSTROH & SAMTLEBEN (1974) were for instance unable to prove a significant difference in kidney growth in patients under 40 and 50 years of age, respectively, and those of older age groups, provided the remaining kidney was un affected by disease In pediatric patients, age dependence would probably be almost negligible

Investigations by DONADIO et coll (1967) and SILBER (1974) would indicate that there is an upper limit for compensatory growth of healthy kidneys Determination of this level should be useful as an adjunct in the examination of remaining kidneys with possible secondary tumor involvement The method of assessment of the kidney size described by EKLÖF & RINGERTZ (1976) was considered likely to facilitate this analysis

The main aim of the present investigation was to establish the type of growth and the size ultimately attained by the contralateral kidney in patients nephrectomized for Wilms' tumor The evaluation was based on the standard material of EKLÖF &



kidney growth as given by EKLOF & RINGERTZ (dotted line)

mine the average increase in kidney length and compare it with the growth of the lumbar segment The remaining kidney increased 2 1 mm in length for every single mm of additional length of the lumbar segment In the standard material the analogous figure was 1 0 mm, and in the series of renal agenesis 1 4 mm These results are exemplified in Fig 4, in which a case sample of each series is illustrated The slope of the three regression lines differs considerably

Twenty-one remaining kidneys were followed for more than 1 1 year, on an average 2 2 years In this group of patients the ultimately recorded kidney length was 2 0±1 1 SD Fifteen patients had been followed for more than 2 5 years, on an average 4 2 years The mean ultimate length of these kidneys, and the range, was the same +2 0±1 1 SD These findings imply that the ultimate length of 98 per cent of the remaining kidneys, following uninephrectomy for Wilms' tumor, will not exceed 4 2 SD

Discussion and Conclusions

Multicystic dysplasia has been considered an equivalent of fetal uninephrectomy LAUFER & GRISCOM analysed the growth of the remaining kidney in this disease entity following removal of the abnormal kidney The measurements were carried out according to the method of HODSON et coll (1962) Since the afflicted kidney may

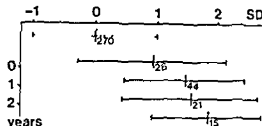


Fig 3 Standard material of EKLÖF & RINGERTZ (dashed horizontal line) Growth of healthy kidney in 35 patients with unilateral Wilms tumor (unbroken lines) Y-axis follow up time from uninephrectomy Mean and range at reviews are given along the x axis Figures indicate the number of kidneys evaluated

the tumor A total of 106 urographies, 26 of them performed preoperatively, were available for review The average follow-up time was 2 0 years Eleven patients were followed for more than 2 5 years, on an average for 4 2 years

The kidney size was assessed according to the method of EKLÖF & RINGERTZ by correlation of the length of the kidney to the length of the lumbar segment L1 to L3 The results were expressed in standard deviations (SD) from the mean No abnormalities of the lumbar spine developed and no injury to the remaining kidney was noted regardless of whether radiation therapy had been given or not Consequently the method used was considered valid also in irradiated cases

Results

Kidney length, measured in the group of patients with unilateral renal agenesis was plotted on a diagram demonstrating the range of renal growth in the standard material of EKLÖF & RINGERTZ (Fig 1) The correlation shows that the regression *line for growth of the solitary kidney begins below the mean The kidneys are in*creasing linearly in length and at an accelerated rate as compared with the standard material As the slope of the regression line is steeper than in the standard material *the solitary kidney will exceed the +2 SD range of the normal variations at a length* of the lumbar segment of approximately 60 mm, i e at 4 to 7 years of age

The mean and the range of ultimately measured kidney length were established *for the 11 patients examined later than at 5 years of age Expressed in the SD of the* normal material of EKLÖF & RINGERTZ the length of the kidneys in this group corresponded to +3 +1 3 SD It appears that 98 per cent of the solitary kidneys in *unilateral renal agenesis would reach a length which does not exceed* +5 6 SD

The remaining kidneys following uninephrectomy for Wilms tumor were examined in the same way (Fig 2) The stars in the diagram indicate the kidney *size of the 26 patients with available preoperative urography* The dots denote the length of these kidneys at later examinations The mean preoperative kidney length exceeded the average of the standard material, as expressed by the calculated range *of* $+0\,9 \pm 1\,2$ *SD (Fig 3) Postoperatively*, a further compensatory growth of the kidney developed, continuing for at least 2 years The ultimately recorded kidney length in cases followed for more than 2 years corresponded to $+1\,9 \pm 0\,9$ SD Correlated to the preoperative lengths of the remaining kidneys the mean length and range were found to be $+1\,5 \pm 0\,8$ SD In 23 kidneys it was possible to deter

By contrast, in a number of the present cases the growth of the remaining kidney continued for more than 2 years (Figs 2, 3) The slope of the regression line of kidney growth was much steeper in the tumor group than in the cases with renal agenesis and the standard material On an average, every mm of increasing lumbar segment length corresponded to an increment in *kidney length of 2 1 mm The ultimate length* of the contralateral kidneys of the tumor group had an upper 96 per cent confidence limit of +4 2 SD The relative kidney length, as compared with the preoperative findings, never exceeded +2 5 SD This implies a faster growth of the remaining kidney following uninephrectomy for Wilms' tumor than for renal agenesis On the other hand compensatory growth seems to continue much longer, resulting in a decidedly taller kidney in the latter group

The fact that the average length of the non-tumorous kidneys already exceeded the mean of the standard material preoperatively was another important detail revealed Incidentally, the same observation was made in another, as yet unpublished material, in which uninephrectomy was carried out for non-neoplastic kidney disease The slope of the regression line was identical in these two groups, and steeper than in renal agenesis

Essentially the same observation has previously been reported by ROCKSTROH & SAMTLEBEN In a series of exclusively non-neoplastic unilateral kidney disease they found the healthy kidney of adult patients preoperatively to be as much as 25 per cent larger than expected Reduction in functional capacity of the abnormal kidney presumably stimulated the healthy partner to compensatory growth

According to HEGEDÜS & MANSOOR (1973), kidney enlargement from expansive processes mainly takes place in a ventro-dorsal direction By contrast, in compensatory hypertrophy the length of the kidney is most affected Nevertheless, also in tumor cases it may be worth while to carefully observe the growth of the remaining kidney, if this exceeds +4 2 SD in length when correlated to the standard material or attains +2 5 SD of the preoperative length, a secondary neoplastic involvement of the remaining kidney may have developed When the findings at urography are ambiguous, an abnormally large size of the kidney would indicate the need for further radiologic exploration, preferably by nephroangiography

Analysis of the late effects on kidney size following nephrectomy for Wilms' tumor are in progress

SUMMARY

The kidney size and renal growth were determined in unilateral renal agenesis and in the remaining kidney following nephrectomy for Wilms' tumor The ultimate length of 98 per cent of the functioning kidneys in renal agenesis is expected not to exceed +5 6 SD In the tumor series the corresponding figure is +4 2 SD

ZUSAMMENFASSUNG

Die Grosse und der Zuwachs der Niere wurden in unilateraler Nierenagenesie und in der Restniere nach Nephrektomie wegen Wilms Tumor bestimmt In Nierenagenesie, uberstieg

retain a certain degree of excretory capacity (YOUNG et coll 1974) and its influence on pre- and postoperative growth of the contralateral kidney remains obscure, this disorder is not considered ideal for determination of the growth of solitary kidneys in general

Unilateral renal agenesis is thought to be a more suitable *model of fetal uninephrectomy*, in addition to the standard material a series of cases with this anomaly served to create a reference for evaluation of the contralateral kidneys secondary to uninephrectomy for Wilms' tumor The results obtained were also compared with those reported by LAUFER & GRISCOM for multicystic dysplasia

In the neonatal period the remaining kidney in patients *uninephrectomized for multicystic dysplasia*, and the functioning kidney in unilateral renal agenesis, frequently have a length below the mean In both groups compensatory growth develops promptly in early infancy

In multicystic dysplasia the remaining kidney continues to grow in length at an above normal rate for 18 months After this time the slopes of the growth curves in the case material of LAUFER & GRISCOM, and in the standard *material employed by* them, were more or less parallel

In the present series of unilateral renal agenesis, the slope of the regression line for kidney growth was steeper than in the standard material Increasing linearly, kidney length exceeded the +2 SD border between 4 and 7 years of age, compensatory growth continuing as a rule for a few more years The extreme renal length on record had an upper 96 per cent confidence limit of +5 6 SD *The average increase* in renal length exceeded the increment in length of the lumbar segment L1 to L3 by approximately 40 per cent Providing there is no evidence of contralateral renal disease, the reported growth pattern and extreme length of a solitary functioning kidney strengthens the possibility of unilateral renal agenesis

The reason for the difference in growth and ultimate renal length in multicystic dysplasia and renal agenesis is not entirely clear, reference should be made to differences in fetal and postnatal kidney function in these types of congenital disorders of the urinary tract, and to as yet hidden factors

In patients uninephrectomized for Wilms tumor, the growth of the remaining kidney, and the ultimate size attained, has received only scant attention Any significant deviation from the expected may hide crucial information and should suggest further radiologic and clinical exploration

VAETH (1964) stated that despite substantial doses of radiation to the remaining kidney the majority of his 5-year survivors had a kidney size at 'the upper limits of the expected, if not larger' LUTENEGGER et coll (1975) recently analysed the growth pattern in a series consisting of 21 patients, 8 of them less than 2 years old at diagnosis Generally speaking, they found that approximately 65 per cent of the renal hypertrophy occurred during the first months after uninephrectomy They considered that by 11 months the hypertrophy was complete, with no further acceleration to be expected Their follow-up time apparently did not exceed 1 year

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MUCOSAL FOLDING IN UPPER URINARY PATHWAYS FOLLOWING URETEROLITHIASIS

G THEANDER and L WEHLIN

In 1964 GWINN & BARNES described thin longitudinal folds in the ureter and renal pelvis observed in 19 patients at urography and, occasionally, at retrograde pyelography This appearance, frequently referred to as 'striation', has since proved a fairly common finding in children The authors stated that urinary infection existed in all cases and in most of them also vesico-ureteral reflux, and then 'usually on the striated side' Similar observations have been reported by POOLE et coll. (1970), who demonstrated such folding in as many as 45 patients aged 1 month to 16 years Several authors have found that the folding often heralds the finding of reflux at subsequent urethrocystography (SILBER & MCALISTER 1970, CREMIN & STABLES 1971, EBEL 1971, FRIEDLAND & FORSBERG 1972)

POOLE et coll obtained specimens at resection of the ureter in 25 of their patients, in 22 the folds were visible also in the specimen, which, in addition, showed inflammation Other authors also confirmed the folding in occasional specimens of urinary pathways previously demonstrated radiologically to have mucosal folds but found no evidence of inflammation (BRAUNE & EBEL 1967, SILBER & MCALISTER, HYDE & WASTIE 1971) Even in specimens obtained from assumedly normal infants tiny folds have been demonstrated in some cases (DAUGHTRIDGE 1969, ASTLEY 1971)

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die Länge nicht +5 6 SD in 98 Prozent der funktionierenden Nieren In der Tumorserie war die entsprechende Ziffer +4,2 SD

RÉSUMÉ

Les auteurs ont étudie les dimensions du rein et la croissance rénale dans l agénésie ré nale unilatérale et sur le rein restant après néphrectomie pour tumeur de Wilms Dans l'agénésie rénale, 98% des reins fonctionnant ne dépassent pas +5,6 DS Dans la série des malades opérés pour tumeur le nombre correspondant est 4 2 DS

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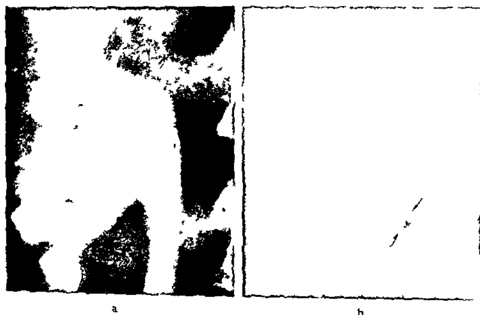
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a b

Fig 1 Case 1 Urography a) Distension and dilatation of right renal pelvis and ureter caused by ureteral *stone* *No mucosal folds* b) No distension after disappearance of stone Mucosal folds at the transition between the renal pelvis and ureter

Results

Although far from all patients with urolithiasis admitted to the department were *examined* by the authors, mucosal folds in the upper urinary pathways were observed in 2 children and in 27 adults

Observations in children

Case 1 An 11 year old girl who at the age of 6 years had been successfully treated for a brief episode of urinary *infection* was admitted because of hematuria and right sided renal colic At urography *on two occasions* delayed excretion was observed in the right kidney and moderate distension *and dilatation* of the right renal pelvis and ureter, caused by a small stone in the distal *part of the ureter* No mucosal folding was observed (Fig 1 a)

Repeated urinalysis including bacterial *culture* revealed *no sign* of infection One month *after* the first attack of pain a *stone sized 3 mm* was passed spontaneously Urography on the following day confirmed that *the* ureteral stone had disappeared as had the delay of excretion and the *distension of* the urinary pathways Tiny mucosal folds were visible in the right renal pelvis and ureter (Fig 1 b)

Case 2 A girl aged 15 years was admitted because of recurrent [illegible]
infection A[illegible]
found in t[illegible]
renal pelv[illegible]
[illegible] Some of these were clubbed and apparently

Thus, although mucosal folds may sometimes occur in the absence of inflammation, an association between radiologically discernible folds and urinary infection has only exceptionally been questioned (DAUGHTRIDGE) Current opinions on the cause of the folding are nevertheless controversial Since urinary infection and reflux are intimately interrelated in childhood, it is not surprising that, in most cases of folding on record, both these abnormalities have been combined and that it has therefore become a matter of dispute whether the folds should be attributed to the infection directly or to the associated reflux

As pointed out by SILBER & MCALISTER, the folds are not visible at urethrocystography at the time when reflux actually occurs They also disappear during urography after compression of the ureters, whereas they are best demonstrated in a phase of incomplete distension, e g, in the beginning of excretion of the contrast medium (BRAUNE & EBEL, ASTLEY, FRIEDLAND & FORSBERG) In this early phase of urography RUDHE (1971) sometimes observed folding even in assumedly normal ureters and pelves He also claimed that 'a hint of striation' may be seen in the area of contraction caused by a peristaltic wave passing along a distended obstructed ureter All these observations suggest that the folding is a transient unspecific phenomenon that may occur in a redundant mucosa at times when the tissue is not being distended

The distension and dilatation of the ureter and pelvis usually accompanying vesicoureteral reflux would thus seem sufficient to explain why, at urography, folding has been most frequently seen in children with urinary infection This explanation has been entirely accepted by some authors (SILBER & MCALISTER, RUDHE, TAYBI 1971, FRIEDLAND & FORSBERG), but others believe that the folds are caused by inflammatory edema or infiltration (BRAUNE & EBEL, WRIGHT 1969, POOLE et coll, EBEL) A third group of authors agree that redundancy of the mucosa plays a part in the causation of folding but feel that radiologically demonstrable folds are unlikely to occur in the absence of chronic infection (GWINN & BARNES, MAYALL 1965, ASTLEY, HYDE & WASTIE 1971) These differences of opinion have practically important implications in that the occurrence of folding, if accepted as a sign of inflammation, would be of specific significance for the prognosis and treatment of the infection

It is thus desirable to clarify whether mucosal folding in the urinary pathways can result from diseases other than urinary infection The fact that such folding was observed by the present authors in 2 children with ureteral stone prompted further search for the phenomenon in urolithiasis Since this condition is relatively uncommon in childhood, the search was extended to adult patients with urolithiasis

Material and Methods The urographies performed by the authors between January 1972 and August 1975 *in patients with urolithiasis were scrutinized* for mucosal folds in the upper urinary pathways In all patients with both these findings the films of any pertinent previous or later urography were also examined and the clinical record sheets were consulted It was checked particularly whether urinary infection had been demonstrated or not



Fig. 3 Case 3 Urography a) Slight dilatation of left ureter and renal pelvis b) Dilatation has disappeared Mucosal folding in renal pelvis

lacked normal papillae No mucosal folding was observed (Fig 2 a c) The findings on the left side were normal

Chemotherapy was instituted and the ureterocele was extirpated Subsequent urine cultures showed no bacterial growth Urography was repeated 3 months after the operation The ureteral stone had disappeared and the renal pelvis and ureter were no longer distended A hint of mucosal folding was seen in the caudal part of the right ureter and definite folding was demonstrated in the right renal pelvis (Fig 2 b d)

Observations in adults

The 27 adult patients found to have mucosal folds in the ureter or renal pelvis ranged in age from 19 to 76 years At urography all had an obstructing ureteral stone and more or less marked dilatation and distension of the urinary pathways above the stone on at least one occasion Mucosal folding was never observed at these examinations but invariably on a later occasion The sequence of events thus documented is exemplified in the following case history

Case 3 A man aged 37 years was examined during an attack of left-sided renal colic. Slight dilatation of the left renal pelvis and ureter above an obstructing stone located caudally in the ureter was found but no mucosal folding (Fig. 3 a) On re-examination 2 months later



a



b



c



d



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after repeated attacks, the obstruction had increased and the pelvis was greatly widened Two weeks later both the stone and the dilatation proved to have disappeared and at that *time mucosal folding was demonstrated in the left renal pelvis* (Fig 3 b)

In 23 cases the folds were not visible until the stone had been passed (16 cases), been removed at operation (6 cases), or had moved spontaneously into the renal pelvis (1 case) The previous dilatation above the stone had then disappeared or substantially diminished In 3 cases the folds were demonstrated at urography despite persistence of the stone in the ureter, but then the stone was no longer obstructive and produced no dilatation In the remaining case the folds were visible at retrograde pyelography via a catheter that had been introduced beyond the persisting ureteral stone and thereby eliminated the obstruction

In most cases the folds were limited to a minor part of the ureter or pelvis They differed in site from one case to another, but they were invariably located on the same side as the previous obstruction In one patient with recurrent stones the review of previous films revealed two episodes, 5 years apart, with a similar sequence of events on the same side Urography had also been carried out between these episodes but then neither urinary obstruction nor folding was demonstrated

In 3 cases the folds were demonstrated within 12 hours after the stone had passed or been removed but, as a rule, radiologic examination following this event was not carried out until after several days or weeks Most of the patients also underwent urography at least once later, the interval differing widely from one case to another In one patient the folds were found to have disappeared after 8 days but usually they persisted longer In one case they were still discernible at urography 14 months after the stone had been removed

Urinalysis was performed at least once before the demonstration of folds in 24 of the 27 adult patients and included bacterial culture in 19 Urinary infection was found in 3 of these patients but not in the others

Discussion and Conclusions

Mucosal folding in the ureter and renal pelvis has been observed much less frequently in adults than in children In a review of urographies CREMIN & STABLES (1971) discovered 5 cases of such folding among 1 200 examinations performed in children younger than 12 years but only 3 in 5 000 examinations of adults Only 6 further adult cases seem to be on record in which folds have been demonstrated at urography (DAUGHTRIDGE 1969) or pyelography (WRIGHT 1969) Already the relatively large number of cases of folding observed in the present investigation of adult patients with urolithiasis is thus sufficient to suggest an association between this disease and mucosal folding

A combination of folds in the upper urinary pathways and urinary concretions has been previously observed in one adult (CREMIN & STABLES 1971) and a few children

(BRAUNE & EBEL 1971), though in these cases the folding was attributed to urinary infection In one of the present children (Case 2) and in 6 of the adults infection may have contributed to the occurrence of folding, but in the majority of the cases urinary infection was excluded The sequence of events recorded in all the present cases before folding was visible provides strong evidence that the folds were due to redundancy of the mucosa following an episode of more or less marked mural stretching

Being a rather common disease in adults urolithiasis may be the most frequent cause of mucosal folding in the urinary pathways in this age The finding of such folds at urography in an adult patient, suggested to have had renal colic caused by a ureteral stone, may therefore be helpful in the establishment of the diagnosis if the stone had already passed This was, in fact, the case when on admission of two of the present patients after such colic their records were not immediately accessible, urography showed unilateral mucosal folding but was otherwise normal, and as the records became available it appeared that previous urography had demonstrated an ipsilateral ureteral stone which had since been passed

In childhood, on the other hand, urolithiasis is far less common and evidently only a rare cause of mucosal folding In most cases of such folding in children the phenomenon is instead associated with urinary infection, but its occurrence may be similarly explained by redundancy of the mucosa following intermittent mural stretching produced by vesico-ureteral reflux It might be objected that reflux has not been invariably demonstrated at urethrocystography in all such cases, but this might be due to disappearance of reflux before the examination had been carried out

Persistence of the mucosal folds at repeated urography has been documented in several children with urinary infection (GWINN & BARNES 1964, CREMIN & STABLES 1971, EBEL 1971), in one case for as long as 21 months Unfortunately it was not stated whether in these cases the infection and reflux also persisted The present investigation affords evidence that in urolithiasis the folds frequently persist for some time after the mural stretching has been relieved and that they can occasionally still be demonstrable after 14 months or longer

It might thus be expected that in children treated for urinary infection urography will sometimes reveal mucosal folding even if both infection and reflux have already been cured The radiologic finding of folds in this rather common category of children should therefore not be considered sufficient to indicate a need of further prolonged or intensified therapy

SUMMARY

Mucosal folds in the ureter c[illegible]
with urolithiasis It appeared f[illegible]
folds occurred in a redundant r[illegible]
including bacterial culture in th[illegible] [illegible]ajority of cases, showed infection in only 3 of the adults

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In most cases the folds were limited to a minor part of the ureter or pelvis. They differed in site from one case to another, but they were invariably located on the same side as the previous obstruction. In one patient with recurrent stones the review of previous films revealed two episodes, 5 years apart, with a similar sequence of events on the same side. Urography had also been carried out between these episodes but then neither urinary obstruction nor folding was demonstrated.

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Urinalysis was performed at least once before the demonstration of folds in 24 of the 27 adult patients and included bacterial culture in 19. Urinary infection was found in 3 of these patients but not in the others.

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A combination of folds in the upper urinary pathways and urinary concretions has been previously observed in one adult (CREMIN & STABLES 1971) and a few children

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KIDNEY SIZE IN CHILDREN

A method of assessment

O EKLÖF and H RINGERTZ

The clinical value of assessment of kidney size by radiologic means is generally recognized Experience has shown that in most cases a quick glance at the film makes it possible to appreciate unequal renal size As a rule, however, it remains impossible to decide by gross estimation whether the dimensions of one or both kidneys are within the normal range Without quantitative methods, symmetrically small or large kidneys are frequently considered to be normal

Although the length may be estimated fairly approximately, generally one of the methods based on the correlation of various kidney measurements to parameters such as age, height, weight, etc is used (HODSON et coll 1962, SIMON 1964, CURRARINO 1965, GATEWOOD et coll 1965) Attempts at increasing the exactness of evaluation by introducing a correction coefficient and certain geometric formulas have been presented (FRIEDENBERG et coll 1965, GUY & MOUNIC 1971, HEGEDÜS 1972) Evaluation of the renal parenchymal thickness based either on a correlation of the total renal length to the bipolar thickness (HODSON et coll 1975), on more or less complicated planimetry (HODSON 1960, HODSON et coll 1962, GUY & MUONIC, JOUVE et coll 1971, WIKSTAD 1975), or on a three-dimensional angiographic assessment (HEGEDÜS, HEGEDÜS & RAVNSKOV 1972) has also been attempted Notwithstanding all these efforts, present methods of appraisal hardly satisfy reasonable

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ZUSAMMENFASSUNG

Mukosafalten im Ureter oder im Nierenbecken wurden bei 2 Kindern und 27 Erwachsenen mit Urolithiasis nachgewiesen Es geht aus der Folge der bei diesen Fallen beobachteten Veränderungen hervor, dass die Falten in einem Überschuss an Mucosa zufolge einer Wanddähnung auftraten Urinanalysen, die in der Mehrzahl der Falle Bakterienkulturen umfassten, zeigten nur bei drei der Erwachsenen eine Infektion

RÉSUMÉ

Les auteurs ont mis en évidence des plis muqueux dans l'uretère ou dans le bassinet rénal chez deux enfants et 27 adultes atteints de lithiase urinaire La suite des événements observés dans ces cas a montré que ces plis se produisent sur une muqueuse agrandie à la suite d'un épisode de distension de la paroi L'examen des urines, y compris la culture bactérienne dans la majorité des cas, n'a montré une infection que chez 3 des adultes

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Fig. 2 Supine film exposed during early phase of urography demonstrating technique of measurement

maining within the normal range Frequently, such changes, common in children, may pass unnoticed or be erroneously evaluated

The aim of the present report is to present a feasible yet reasonably sensitive method of determining kidney size, taking all these aspects into account

Material and Methods

A computerized analysis of several measurements and combinations of measurements showed that from a practical point of view the length of the kidney is the best parameter for assessment An exactly linear correlation exists between the length of the kidney and that of the lumbar segment L1 to L3 including the intervertebral spaces comprised by these vertebrae Using this relationship, the normal range of kidney lengths was determined for L1 to L3 measurements between 2 5 and 11 5 cm in a series of 135 patients with normal urography This interval covers all patients in the pediatric age group The material comprised 15 patients for every cm of lumbar length The sexes were about equally represented No difference was made between boys and girls (FRIEDENBERG et coll) Both kidneys were measured The left kidney appears, as a rule, approximately 2 per cent longer than the right one This slight difference was duly considered and included in the Table and the graphs

The distribution of the material as kidney length correlated to that of the lumbar spine is demonstrated in Fig 1 The procedure of measurement appears in Fig 2

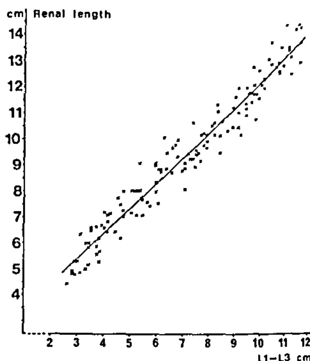


Fig 1 Distribution of the material

demands for statistical accuracy and easy employability Neither the relation between the length of the two kidneys in healthy children, nor the relative changes occurring in disease have so far achieved any appreciable degree of attention Thus, rather marked relative alterations in kidney size may occur, both kidneys still re-

Table

Framed The normal range (±2 SD) of kidney length in mm given for each mm of L1 to L3 length Outside the frame the length of the lumbar segment is given in tens of mm along the y-axis and in units along the x-axis Application Length of the lumbar segment 62 mm Normal range of renal length 72 to 101 mm The normal range of the ratio right kidney length/left kidney length covers the interval 1 12 to 0 84

	0	1	2	3	4	5	6	7	8	9
20	—	—	—	—	—	36– 65	37– 66	38– 67	39– 68	40– 69
30	41– 70	42– 71	43– 72	44– 73	45– 74	46– 75	47– 76	48– 77	49– 78	50– 79
40	51– 79	52– 80	53– 81	54– 82	55– 83	56– 84	57– 85	58– 86	59– 87	60– 88
50	61– 89	62– 90	63– 91	64– 92	65 93	66– 94	67– 95	68– 96	69– 97	70– 98
60	70– 99	71–100	72–101	73–102	74–103	75–104	76–105	77–106	78–107	79–108
70	80–109	81–110	82–111	83–112	84–113	85–114	86–115	87–116	88–117	89–118
80	90–118	91–119	92–120	93–121	94–122	95–123	96–124	97–125	98–126	99–127
90	100–128	101–129	102–130	103–131	104–132	105–133	106–134	107–135	108–136	109–137
100	109–138	110–139	111–140	112–141	113–142	114–143	115–144	116–145	117–146	118–147
110	119–148	120–149	121–150	122–151	123–152	124–153	—	—	—	—

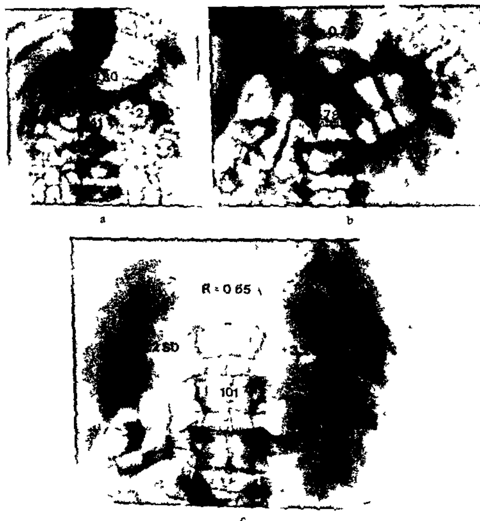


Fig 5 Films from a case followed for approximately 14 years a) Exposed at 0 7 years of age, b) at 7 4 years of age and d) at 13 4 years of age The change in ratio indicates reduced growth capacity on the right side the left kidney grows at a constant level of 3 to 3 5 SD

the method applied in practice The kidney in the example given has a length of about 5 SD A clinical application is exemplified in Fig 5 The case selected for illustration has been examined with repeat urographies for several years The patient a boy, was initially treated for bilateral hydronephrosis, thought to be secondary to massive ureteric reflux and primary bladder neck obstruction The three examinations at 0 7, 7 4 and 13 4 years of age show a kidney ratio which as early as at the first examination was below 0 84, the lower 2 sigma border of the normal variations, and thus considered pathologic During the further course of the disease,

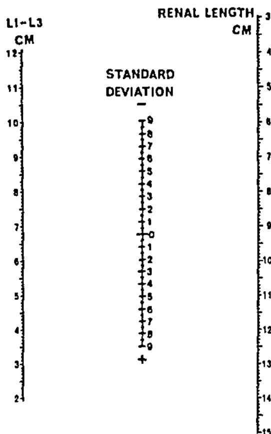


Fig 3

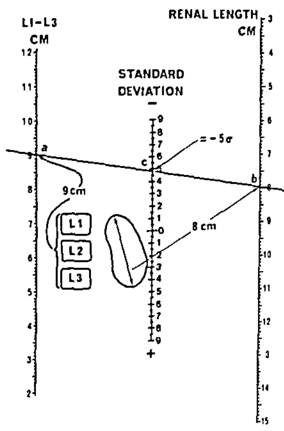


Fig 4

Fig 3 Nomogram for length of any given kidney in standard deviations

Fig 4 The method in practice The length of the selected kidney is at a level of 5 SD

To allow optimum outlining of the kidney the beam has to be coned down to cover solely the kidney areas A supine film exposed during the nephrographic or early excretory phase of urography, before compression has been applied, is used for this purpose This single film provides all necessary information for the assessment, and there is no need to look into the case history for height, weight or other clinical data Retrospective evaluation is feasible, as is comparison with films from other hospitals The value of the method is, of course, limited to some extent in cases of concurrent spinal deformities, but relative changes appearing during the course of disease may be assessable

The right to left kidney length ratio was determined, to make comparison of consecutive examinations easier This ratio has a 96 per cent probability interval between 1 12 and 0 84 It is independent of the length of the lumbar spine In the Table, the normal range of kidney length is given for all lengths of the lumbar segment L1 to L3 included in this report

A nomogram (Fig 3) has been designed for a precise presentation of the deviation from the mean of the kidney at any length of the lumbar spine Fig 4 illustrates

Based on extensive experience of the method in practice, the kidney length is considered an adequate guide to kidney size It is as useful for isolated measurements as for long term assessments of renal growth Besides the simplicity of the method the mode of presentation of results constitutes an additional advantage, kidney length may either be expressed in standard deviations or as a ratio As this ratio depends on renal length alone, a comparison with previous films or films from other hospitals is feasible and does not call for knowledge of the patient's height, weight or other data Not even the focus film distance is a necessary adjunct

Some reports (WOLPERT 1965, LEBOWITZ et coll 1975) indicate a certain degree of increase in renal length during the course of urography The effect of this potential error of the method is reduced if the measurements are confined to films exposed in the nephrographic or early excretory phase of urography

In the past, some authors, assessing kidney size in adults, used the length as the single guide line (BILLING 1954, MOELL 1956) In the growing child, however, correlation of kidney length to another easily available parameter is a prerequisite for a meaningful evaluation

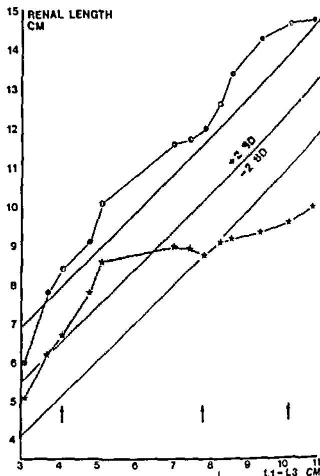
The first report on the correlation of kidney length to parameters as age, height and weight appears to be that of HODSON et coll (1962) Their graph showing kidney length plotted against age has since then been widely used by others, who have modified the initial method The graph, however, cannot be accepted from the statistical point of view because of the, by definition, inadvertent distribution of approximately 96 per cent of the normal material within the range of one standard deviation

SIMON (1964), evaluating kidney size in an adult series, correlated the length to a vertebral segment CURRARINO introduced this correlation into the practice of pediatric radiology by superimposing the kidney lengths of 50 children from 0 to 14 years on the graph for renal length of HODSON et coll (1962) GATEWOOD et coll performed further correlations using the same graph

To achieve a feasible presentation of obtained measurements LEBOWITZ et coll introduced the 'growth and hypertrophy chart' of LAUFER & GRISCOM (1971) into the routine Contrary to the opinion expressed in the present report, they found the correlation of the kidney length to a given lumbar segment helpful at the initial evaluation 'but not so in the following renal growth' It would appear that the pitfalls of their method are avoidable by using the method now presented

FRIEDENBERG et coll made an extensive computer analysis correlating the product of renal length and width to the body surface area They also designed graphs for reference aiming at a simplified quantification of changes in their renal index with specific diseases

As early as in 1960 HODSON used the compensation planimeter in an attempt to correlate kidney size as expressed by surface area to body area The range of normal variations being about 30 per cent, he found 'the outstanding observation emerging from study, to be the registered symmetry in size and renal substance between the



... the same case ...

sents the normal range for the combination of length of the kidney and the length of the lumbar segment L1 to L3 Arrows indicate the time when the films in Fig 5 were exposed

the ratio diminished continuously reaching the level of 0 65 A notable fact is, that both kidneys at the first examination had a length above the mean value While subsequently the right kidney increased only slowly in length, the increase on the left side was essentially normal and approximately at the same level of confidence as before The alteration in kidney size becomes easier to demonstrate and evaluate if a diagram is used (Fig 6) The dotted field covers the normal interval for the combination of lumbar length along the x-axis and kidney length along the y-axis In the present case, an initial period of nearly parallel kidney growth was followed by almost complete cessation of growth on the right side but with a continuous increase in length, at an approximately constant rate above normal, on the left side

Discussion and Conclusions

A practical and simple, yet reasonably sensitive method for the evaluation of kidney size in children has been presented A computerized analysis of measurements and combinations of measurements showed the kidney length to be the ideal parameter for assessment

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two kidneys in most healthy individuals' In another report HODSON et coll (1962) found 'close correlation between age, body weight, and length and cross sectional areas of the kidneys' Along the same lines, either by simple reduction of the calyceal pelvic area from the total sectional kidney area, or by use of more or less sophisticated formulas, other types of planimetry of the kidneys have been carried out (GUY & MOUNIC, JOUVE et coll) Recently, planimetry of the kidney has been used for correlation to renal function (WIKSTAD) None of these methods seems to have achieved general application This might be due to relatively complicated and time consuming procedures implicated in the methods, in addition to which their statistical reliability remains ambiguous

In clinical routine work the three-dimensional determination of renal volume (HEGEDÜS) or renal cortical volume (HEGEDÜS & RAVNSKOV) is impracticable particularly so in pediatric radiology in view of the radiation dose

This survey of available methods of assessment of kidney size should emphasize the need for a simple technique The method presented is meant to solve this problem it is easily applicable in daily routine, it serves as a screening procedure, and obtained data are given in a simple form

SUMMARY

A method for assessment of kidney size in pediatric practice is presented Length of the kidney is correlated to length of the lumbar segment L1 to L3 including the intervertebral spaces comprised by these vertebrae The result may either be expressed in standard deviations or as a kidney ratio The method makes comparison with films from previous examinations or other hospitals feasible without access to any other data than those available in the film The method also serves the purpose of properly assessing the growth of the kidneys

ZUSAMMENFASSUNG

Eine Methode um die Nierengrosse bei Kindern festzustellen wird beschrieben Die Länge der Niere wird zur Lange des Segments L1 bis L3 mit den dazwischenliegenden Intervertebralraumen korreliert Das Ergebnis kann entweder als Standardabweichung oder durch einen Verhältniswert der Niere ausgedruckt werden Die Methode macht einen Vergleich mit Filmen von fruhreren Untersuchungen oder von anderen Krankenhausern moglich ohne Zugang zu anderen Daten als denen die der Film enthalt Die Methode dient auch dem Zweck das Wachstum der Nieren genau festzustellen

RESUMÉ

Les auteurs présentent une méthode pour déterminer la taille des reins chez des enfants La longueur du rein est corrélée à la longueur du segment de L1 à L3 en y comprenant les deux espaces intervertébraux Le résultat peut être exprimé soit en déviation standard soit en rapport rénal Cette méthode permet la comparaison avec des films d examens faits auparavant ou bien faits dans d'autres hôpitaux sans nécissiter d autres données que celles qui sont sur le film Cette méthode sert aussi à apprécier exactement la croissance des reins

Table

Normal range and numerical values of mean and SD of right/left kidney length ratio as calculated from a standard material and from 108 cases of uncomplicated reduplication of the urinary tract

	Average	SD	±2 SD range
Standard material	0 98	0 07	0 84–1 12
Uncomplicated right-sided reduplications	1 03	0 11	0 81 1 25
Uncomplicated left-sided reduplications	0 89	0 09	0 71–1 07

The results of this evaluation were thought to be of clinical significance in facilitating early recognition of abnormality in the size of the anomalous kidney

Material and Methods

The material consisted of 106 girls and 36 boys with a unilateral duplication anomaly Reduplication was present on the right side in 61 cases and on the left side in 81 In 30 girls and 4 boys urography revealed a complicating ectopic ureterocele, on the right side in 15 patients and on the left in 19 These figures do not signify any statistical difference between the two groups All age groups from early infancy to adolescence were represented

Correlation of the length of the kidney to that of the lumbar vertebrae L1 to L3, including the intervertebral spaces in between, provides a reasonably reliable means of assessing kidney size (EKLÖF & RINGERTZ) The result may either be expressed in absolute terms in standard deviations (SD) from the mean, or—independently of the length of the lumbar segment—relatively, as the ratio of the right to left kidney length

Absolute kidney size and the ratio of kidney lengths were determined in 108 cases of uncomplicated duplication anomaly The ratios were compared with those given in the standard material of EKLÖF & RINGERTZ (Table)

Ratios of the kidney lengths obtained in the group of uncomplicated reduplication of the urinary tract were then compared with those calculated in patients with complicating ectopic ureterocele The latter group included all unilateral cases previously reported by LUNDIN & RIGGS

Results

The ratio of right to left kidney lengths in the series of uncomplicated reduplication appears in Fig 1 The normal range of the standard material, and the ±2 SD from the mean in the patients with the duplication anomaly is given in the Table As expected the kidney length on the anomalous side as a rule exceeds that of the contralateral kidney Thus, 74 per cent of the reduplicated kidneys were longer than the mean, 23 per cent exceeding the +2 SD limit More interesting is the fact that

FROM THE DEPARTMENT OF PEDIATRIC RADIOLOGY (DIRECTOR O EKLÖF), KAROLINSKA SJUKHUSET, S-104 01 STOCKHOLM, SWEDEN

KIDNEY SIZE IN CHILDREN WITH UNILATERAL URINARY DUPLICATION

O EKLÖF, H RINGERTZ and H TSCHÄPPELER

Duplication of the renal pelvis and ureter is the most common variation of the urinary tract It was found in approximately 0 7 per cent of adults and in 0 3 per cent of children in a large autopsy material (CAMPBELL 1951) In clinical series, much higher frequencies have been reported, between 2 7 and 4 2 per cent (HARTMAN & HODSON 1969) The difference in incidence has been attributed to increased morbidity in afflicted patients

Impaired drainage of one or both of the reduplicated collecting systems may result in urinary infections and occasionally pyelonephritis Associated anomalies are far from uncommon, and are usually related to the ureteric insertion

The radiologic manifestations of reduplication and associated anomalies are well known, but comments on the size of the kidney in these conditions are few and vague (LUNDIN & RIGGS 1968, HARTMAN & HODSON, SILBER 1974)

The aim of this investigation was to establish whether any differences in kidney size exist between patients with the duplication anomaly, and the standard material of EKLÖF & RINGERTZ (1976) A recently reported material reviewed from other aspects, with duplication of the renal collecting systems complicated by ectopic ureterocele (EKLÖF & MAKINEN 1974), was chosen to demonstrate the influence of one of many associated anomalies on the appearances of the kidney

Submitted for publication *31 January 1976*

Table

Normal range and numerical values of mean and SD of right/left kidney length ratio as calculated from a standard material and from 108 cases of uncomplicated reduplication of the urinary tract

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Eighty six per cent of the anomalous kidneys in patients presenting with an ectopic ureterocele had a length above the mean Fourteen per cent of the kidneys were shorter than the average, and 3 per cent were below −2 SD

Discussion and Conclusions

Duplex kidneys are, in current literature, as a rule supposed to be as large as or larger than the contralateral one LUNDIN & RIGGS, reviewing a series comprising 31 children with a duplication anomaly and ectopic ureterocele, found 26 with a kidney length, on the anomalous side, exceeding the mean, and 5 to be longer than +1 SD The evaluation was performed according to the methods of HODSON et coll (1962) and GATEWOOD et coll (1965), implying a statistically questionable result (EKLÖF & RINGERTZ) LUNDIN & RIGGS mentioned that 'the same degree of kidney enlargement applied to reduplicated kidneys without ectopic ureterocele' In adults, HARTMAN & HODSON found the duplex kidney, if otherwise normal, to be 1 to 3 cm longer than the contralateral one, and only rarely equal in size The anomalous kidney, unless obviously diseased, was never shorter than the contralateral one Bilateral duplication was said to result in bilateral renal enlargement In a material consisting of 17 adults with unilateral duplication SILBER (1974) found the mean length of the ipsilateral kidney to be 14 5 cm The contralateral kidney, used as a control, was on average 1 5 cm shorter In the present series, the length of the duplex kidney mostly exceeded the mean This statement proved valid particularly in reduplications complicated by an ectopic ureterocele The finding is somewhat unexpected because the upper pole of this type of duplex kidney is almost invariably the site of inflammatory processes and dysplasia resulting in shrinkage of the parenchyma (ERICSSON & IVEMARK 1958) On the other hand these abnormalities may perfectly well explain the occasional occurrence of a kidney smaller than average in both groups of duplication anomaly As a matter of fact, the incidence of complications, notably infections, is strikingly high in all patients with reduplication of the urinary tract (JOHNSTON 1961, RATNER et coll 1961) A large kidney, again, may be secondary to obstructive uropathy

From the practical point of view this would mean that neither assessed relative nor absolute kidney size will allow any definitive conclusions to be drawn from the data obtained at a single examination A duplex kidney length below mean should indicate inflammatory shrinkage of the dysplastic parenchyma of the upper pole By contrast, a length above mean does not necessarily imply normal renal parenchyma to be present on microscopy The cause of any deviation from the mean in the individual patient therefore needs to be carefully analysed in other diagnostic terms as well Differences in renal length ratio observed at serial examinations are particularly valuable for determining minor deviations in kidney size As a guide line in practice, the most important normal ranges and numerical values of the SD are given in the Table

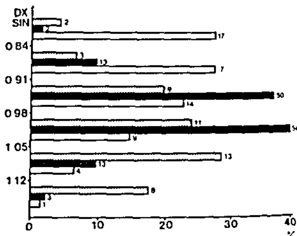


Fig 1 Distribution of ratios of the right to left kidney lengths in a standard material cated and tion anomalies

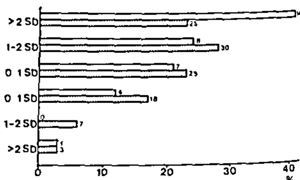


Fig 2 Distribution of ratios of the right to left kidney lengths in uncomplicated unilateral duplication anomalies (dotted columns) and in reduplications complicated by ectopic ureteroceles (white columns)

26 per cent of the patients had a duplicated kidney shorter than the mean In 3 per cent of cases the length was below 2 SD

A commensurable shift existed in ratios of kidney lengths, which revealed a wider normal range in patients with a unilateral duplex kidney when compared with the range of the standard material The numerical value of 1 SD increased from 0 7 in the latter group to 0 11 in right-sided and to 0 09 in left-sided duplication anomalies The reason for this difference is poorly understood Therefore, an integrated presentation of the results was avoided and the results were given separately for the two kidneys

The same trend was evident in the patients with complicating ectopic ureterocele (Fig 2) In this figure all reduplications included in the material have been made commensurable by expressing them in SD equivalent with the SD calculated on the basis of the standard material (EKLÖF & RINGERTZ) As a consequence, no real numerical values of the ratios are given Cases of simple unilateral reduplication were then compared with those complicated by an ectopic ureterocele The deviation from the mean ratio of 0 98 of the standard material increased further in the patients with ectopic ureterocele However, this difference is not statistically significant

Eighty-six per cent of the anomalous kidneys in patients presenting with an ectopic ureterocele had a length above the mean Fourteen per cent of the kidneys were shorter than the average, and 3 per cent were below −2 SD

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Duplex kidneys are, in current literature, as a rule supposed to be as large as or larger than the contralateral one LUNDIN & RIGGS, reviewing a series comprising 31 children with a duplication anomaly and ectopic ureterocele, found 26 with a kidney length, on the anomalous side, exceeding the mean, and 5 to be longer than +1 SD The evaluation was performed according to the methods of HODSON et coll (1962) and GATEWOOD et coll (1965), implying a statistically questionable result (EKLÖF & RINGERTZ) LUNDIN & RIGGS mentioned that 'the same degree of kidney enlargement applied to reduplicated kidneys without ectopic ureterocele' In adults, HARTMAN & HODSON found the duplex kidney, if otherwise normal, to be 1 to 3 cm longer than the contralateral one, and only rarely equal in size The anomalous kidney, unless obviously diseased, was never shorter than the contralateral one Bilateral duplication was said to result in bilateral renal enlargement In a material consisting of 17 adults with unilateral duplication SILBER (1974) found the mean length of the ipsilateral kidney to be 14 5 cm The contralateral kidney, used as a control, was on average 1 5 cm shorter In the present series, the length of the duplex kidney mostly exceeded the mean This statement proved valid particularly in reduplications complicated by an ectopic ureterocele. The finding is somewhat unexpected because the upper pole of this type of duplex kidney is almost invariably the site of inflammatory processes and dysplasia resulting in shrinkage of the parenchyma (ERICSSON & IVEMARK 1958) On the other hand these abnormalities may perfectly well explain the occasional occurrence of a kidney smaller than average in both groups of duplication anomaly As a matter of fact, the incidence of complications, notably infections, is strikingly high in all patients with reduplication of the urinary tract (JOHNSTON 1961, RATNER et coll 1961) A large kidney, again, may be secondary to obstructive uropathy

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SUMMARY

Absolute kidney length and the ratio of right to left kidney lengths were estimated by the method of EKLÖF & RINGERTZ in a series of 142 patients with unilateral renal duplication The anomalous kidney was frequently found to be larger than the contralateral one, particularly when associated with ectopic ureterocele, which was present in 34 patients Nevertheless a substantial number of reduplicated kidneys had a length below mean some of them actually below −2 SD

ZUSAMMENFASSUNG

Die absolute Nierengrösse und das Verhaltnis der linken zur rechten Niere wurde nach der Methode von EKLÖF & RINGERTZ bei 142 Patienten mit unilateraler Verdoppelung gemessen Die abnormale Niere ist haufig grosser als die kontralaterale, besonders wenn diese mit einer ektopischen Ureterocele verbunden ist, was bei 34 Patienten beobachtet wurde Eine erhebliche Anzahl der verdoppelten Nieren hatte eine Lange unter der Norm einige von denen sogar unter 2 Standardabweichungen

RÉSUMÉ

Sur une série de 142 malades ayant une duplication unilatérale, la mesure absolute de la longueur du rein et le rapport de la longueur du rein droit à celle du rein gauche ont été estimés par la méthode d'EKLOF & RINGERTZ Les auteurs ont constatés que le rein anormal est souvent plus volumineux que le rein controlatéral, en particulier quand l'anomalie est associée avec une urétérocèle ectopique qui existait chez 34 malades Cependant un nombre important de reins doubles ont une longueur inférieure à la moyenne, dans certains cas inférieure de moins 2 DS

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LYMPHOID HYPERPLASIA OF THE COLON IN CHILDHOOD

G THEANDER and B TRÄGÅRDH

Lymphoid tissue is normally present throughout the human intestine In the large bowel it forms discrete nodules known as lymph follicles, which are located mainly in the submucosa but may extend through a hiatus in the muscularis mucosae and cause slight protrusion of the mucosal surface Many of these protrusions have a characteristic central concavity, referred to as umbilication

The lymph follicles are usually only 1 to 2 mm or less in diameter They are then invisible on ordinary gross inspection but may be macroscopically counted after partial removal of the mucosa Using this technique DUKES & BUSSEY (1926) examined the bowel of 111 adults and 6 children The number of follicles per square centimeter was found to increase slightly from the ascending to the sigmoid colon The average figure ranged from less than 1 to 13 in the entire series (mean 3 8) but was higher in the children (range 4 to 13, mean 8 1) The follicles were more abundant in patients who had died from peritonitis (7 cases), but no other association with any disease was found

In some cases, however, the lymph follicles in the colon are larger and cause grossly visible protrusions of the mucosa This condition, usually described as lymphoid hyperplasia but sometimes as pseudoleukemia or by various other terms, has been considered fairly uncommon ROBINSON et coll (1973), who systematically

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investigated the entire intestine at 1 000 consecutive autopsies, found lymphoid hyperplasia in 30 cases, the large bowel being involved in 26 The number of follicles in the affected areas ranged from 4 to 12 per square centimeter

Radiologic examination of the colon in lymphoid hyperplasia may demonstrate not only the numerous mucosal protrusions but also the minute umbilication of their surface CAPITANIO & KIRKPATRICK (1970) considered double contrast examination necessary for their recognition At such an examination they had observed the condition in 19 infants and children aged 6 months to 8 years

With a similar technique FRANKEN (1970) found evidence of lymphoid hyperplasia in as many as 17 of 29 children This unexpectedly high incidence calls attention to the importance of recognizing the condition and to the clinical significance of the radiologic findings The present report is concerned with these aspects of lymphoid hyperplasia in childhood Sites other than the large bowel and rectum are not considered

Material and Methods

All films obtained at examination of the colon in infants and children at this department in 1961 (107 cases) and in 1966 (122 cases) were reviewed for lymphoid hyperplasia without knowledge of the history or clinical findings The criteria used for the diagnosis in these series were (1) numerous uniform mucosal protrusions not exceeding 5 mm in size, (2) typical umbilication of several of the protrusions (3) no evidence of mural infiltration ulceration or constriction

Ever since 1954 the double contrast examination of the colon has been used routinely at the department Exceptions have been suggestion of intestinal malformation in newborns, and urgent examination in acute abdominal disease irrespective of age In such cases a conventional barium enema has been used Both these procedures are thus represented in the review

The findings made in the review were grouped according to age and examination procedure The record sheets of all cases with evidence of lymphoid hyperplasia were then consulted for the indication of the examination Further inquiry into these cases was made in 1975 to collect all available clinical information This follow-up thus covered at least 13 and 8 years, respectively Any radiologic colon examination performed in the interval was also reviewed

Further experience with the radiology of lymphoid hyperplasia was currently obtained from more recent cases examined These are briefly exemplified in a few selected case histories

Results

Review series

Of the 229 patients, 153 had been examined with the double contrast technique In the remaining 76 cases a conventional barium enema had been given, usually because of suggested intussusception and only exceptionally because of malformation

Table 1

Radiologic procedure and observed incidence of lymphoid hyperplasia of the colon in 229 infants and children distributed according to age

Age (years)	Number of cases			Lymphoid hyperplasia
	Double contrast examination	Barium enema	Total	
0–2	8	43	51	5
3–5	27	22	49	4
6–8	30	6	36	3
9–11	35	2	37	7
12 14	53	3	56	5
Total	153	76	229	24

Table 2

Presenting symptoms according to age in 24 infants and children with radiologically diagnosed lymphoid hyperplasia of the colon

	Age in years					Total
	0–2	3–5	6–8	9–11	12 14	
Abdominal pain	1	2	2	4	5	14
Rectal bleeding	2	1	2	1	—	6
Diarrhoea	2	—	—	—	2	4
Constipation	—	2	—	1	—	3
Miscellaneous	—	1	—	2	—	3

(atresia malrotation of bowel, or aganglionosis) No patient had been examined with both procedures The number of films obtained differed considerably from one case to another, and was smallest (usually 1 to 4) in those examined for intussusception

The age distribution of the material is given separately for either procedure in Table 1 Conventional barium enema had, as expected, been dominantly employed only below 3 years of age and been unusual above the age of 5 The total number of cases was fairly evenly distributed over the age groups

Radiology Evidence of lymphoid hyperplasia was found in 24 patients All but 2 of these had been examined with the double contrast procedure The observed incidence of the condition was thus 14 4 per cent with this type of examination, but less than 3 per cent with the enema procedure

Each of the 2 lowest age groups included one of the cases in which lymphoid hyperplasia was diagnosed with the enema procedure The observed age distribution

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With a similar technique FRANKEN (1970) found evidence of lymphoid hyperplasia in as many as 17 of 29 children This unexpectedly high incidence calls attention to the importance of recognizing the condition and to the clinical significance of the radiologic findings The present report is concerned with these aspects of lymphoid hyperplasia in childhood Sites other than the large bowel and rectum are not considered

Material and Methods

All films obtained at examination of the colon in infants and children at this department in 1961 (107 cases) and in 1966 (122 cases) were reviewed for lymphoid hyperplasia without knowledge of the history or clinical findings The criteria used for the diagnosis in these series were (1) numerous uniform mucosal protrusions not exceeding 5 mm in size, (2) typical umbilication of several of the protrusions (3) no evidence of mural infiltration, ulceration or constriction

Ever since 1954 the double contrast examination of the colon has been used routinely at the department Exceptions have been suggestion of intestinal malformation in newborns, and urgent examination in acute abdominal disease irrespective of age In such cases a conventional barium enema has been used Both these procedures are thus represented in the review

The findings made in the review were grouped according to age and examination procedure The record sheets of all cases with evidence of lymphoid hyperplasia were then consulted for the indication of the examination Further inquiry into these cases was made in 1975 to collect all available clinical information This follow-up thus covered at least 13 and 8 years, respectively Any radiologic colon examination performed in the interval was also reviewed

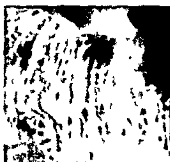
Further experience with the radiology of lymphoid hyperplasia was currently obtained from more recent cases examined These are briefly exemplified in a few selected case histories

Results

Review series

Of the 229 patients, 153 had been examined with the double contrast technique In the remaining 76 cases a conventional barium enema had been given, usually because of suggested intussusception and only exceptionally because of malformation





a b

Fig. 2. Case 2 (brother to case 1) Lymphoid hyperplasia initially mistaken for familial polyposis a) Double contrast examination, b) post-evacuation film.

examination These 2 patients were those in whom lymphoid hyperplasia was demonstrated with the enema procedure The pain in the other cases was described as being uncharacteristic with periumbilical or diffuse abdominal location

Follow up Further information obtained in 1975 may be briefly summarized as follows The pedunculated polyp discovered in one boy had been extirpated and proved benign The other boy, initially suggested of having a small polyp, had a double contrast examination one year later The findings were then normal

Of the remaining 22 children with evidence of lymphoid hyperplasia, only 8 were found to have been readmitted to this hospital (which is the only one in Malmö) In 2 of these cases the colon had again been examined with double contrast after 2 and 7 years respectively The symptoms had then been abdominal pain, but the radiologic findings were normal Of the other 6 children one had been under observation for assumed appendicitis a few years later Another had been seen several times because of allergy and psychoneurosis, 3 had been admitted because of accidental injury, and one because of a hiatus hernia, but these cases had no abdominal symptoms



Fig 1 Case 1 Member of polyposis family Double contrast examination Lymphoid hyperplasia of colon no polyps

of the condition in the entire review is given in Table 1 which reveals no significant difference in incidence with age However in view of the fact that as many as 4 of the 5 cases of lymphoid hyperplasia below the age of 3 years were detected among only 8 patients examined with double contrast the incidence recorded in this age group appears proportionately high

In all cases the lymphoid hyperplasia had escaped recognition in the original report the radiologic findings had been considered normal except in 2 cases One of these was in a 4 year old boy who was found to have a pedunculated polyp in the rectum The other was in a boy aged 11 years in whom a small sessile polyp was suggested

Symptoms and signs The radiologic examination in the patients with lymphoid hyperplasia had been prompted mainly by abdominal pain in 14 cases rectal bleeding in 6 diarrhoea in 4 and constipation in 1 case Miscellaneous other findings had been loss of appetite (2 cases) and signs of anemia (1 case) Six patients had more than one symptom

The distribution of the presenting symptoms with age is given in Table 2 which shows that 5 of the 6 children with rectal bleeding were below 9 years whereas pain had been a more common complaint above this age In 2 young children the character of the pain suggested intussusception but this diagnosis was excluded by the radiologic



Fig 4 Case 4 Duodenal atresia malrotation of bowel and lymphoid hyperplasia demonstrated at 2 days of age *Barium enema*

double contrast examination (Fig 2) The umbilications initially escaped recognition, and the findings were believed to represent an early stage of polyposis, but rectoscopy showed lymphoid hyperplasia without any polyps The radiologic findings were similar on all occasions

Clinical follow up in both cases is continuing The patients had remained free of symptoms at the age of 15 and 11 years, respectively, and rectoscopy was normal

Case 3 A girl aged 11 years was examined after 2 episodes of diarrhoea and rectal bleeding A double contrast examination of the colon showed the entire colonic and rectal mucosa to be crowded with round protrusions, 1 to 2 mm in size (Fig 3) Though close inspection revealed minute umbilications in the centre of several protrusions, the findings were considered as representing inflammatory and ulcerative abnormalities Rectoscopy also suggested inflammatory edema of the mucosa but no ulceration was observed

A repeat double contrast examination was performed 2 years later after continuous conservative treatment for assumed ulcerative colitis The mucosal protrusions had disappeared and the radiologic findings were normal The previous films were reevaluated, and a retrospective diagnosis of lymphoid hyperplasia was made In the meantime the girl had been entirely free of symptoms and repeated rectoscopy had been normal except that, on one occasion, slight lymphoid hyperplasia had been observed at the sigmoid junction

Case 4 A baby girl was examined 2 days after birth because of vomiting and small urine volumes Urography was normal but survey films of the abdomen and barium enema

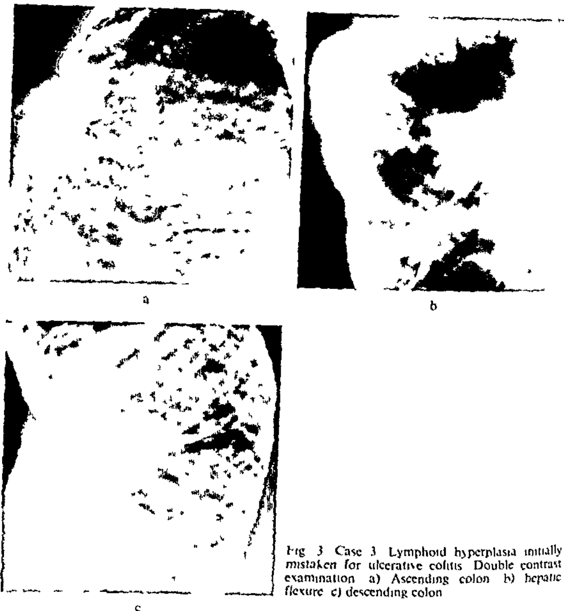


Fig 3 Case 3 Lymphoid hyperplasia initially mistaken for ulcerative colitis Double contrast examination a) Ascending colon b) hepatic flexure c) descending colon

Case reports

Cases 1 and 2 A girl and her 3 1/2 year younger brother repeatedly underwent double contrast examination of the colon at 1-year intervals from 9 to 13 and from 5 to 9 years of age, respectively They had no symptoms, but their mother had died of carcinoma of the [illegible] nal uncle, who had also malignant [illegible] to 3 mm in size, were found at all examinations They were scanty in the rectum but numerous in the ascending colon and coecum (Fig 1) Rectoscopy confirmed lymphoid hyperplasia, which was also verified by biopsy

In the boy a large number of similar protrusions were distributed throughout the colon and rectum These were visible already on a post evacuation film obtained before the actual

hyperplasia in 3 children reported by FRANKEN (1970) as well as in one of the present cases In 2 sisters with microscopically confirmed familial polyposis preoperative colon examination had suggested lymphoid hyperplasia (NEITSCHMAN et coll 1973), and in 3 infants on record lymphoid hyperplasia was observed following neonatal enterocolitis (RABINOWITZ et coll 1968)

Lymphoid hyperplasia of the colon has also been observed in combination with dysgammaglobulinemia (WOLFSON et coll 1970) Furthermore, it has been claimed to occur as an initial stage in the development of malignant lymphomas (BARBA 1952) as well as of Crohn's disease (MORSON 1972) According to a statement made by SYMMERS in 1948, radiation therapy had at that time become the accepted treatment, but also cortisone has been advocated Cumulative evidence suggests, however, that lymphoid hyperplasia is usually, if not always, a benign condition probably reflecting a non specific response of lymphoid tissue in a variety of diseases (infection, allergic reactions, etc)

FRANKEN who compared the symptoms in 17 children with and 12 without radiologic evidence of lymphoid hyperplasia of the colon, found no connection between this condition and the history or clinical findings In 30 cases of lymphoid hyperplasia discovered at autopsy, ROBINSON et coll (1973) found no association with any specific symptomatology in the clinical records Of the 19 cases diagnosed by CAPITANIO & KIRKPATRICK (1970) at double contrast examination of the colon as many as 13 had presented with rectal bleeding, but since at their department children without bleeding were apparently only exceptionally examined with the double contrast technique, these figures hardly seem relevant In the present review series only 6 of 24 children with lymphoid hyperplasia had presented with bleeding, and no characteristic symptomatology could be attributed to the hyperplasia

There seems to be no substantial series of patients with lymphoid hyperplasia in which clinical or histologic follow up has been systematically performed, but disappearence of the radiologic abnormalities has been documented in some cases, e g, by CAPITANIO & KIRKPATRICK The present investigation affords further examples of the spontaneous disappearence of lymphoid hyperplasia in children It is also noteworthy that no case of potential malignancy or of Crohn's disease was revealed in the cases followed up for more than 8 or 13 years

The present observations thus support the opinion that lymphoid hyperplasia of the large bowel in childhood should be considered a benign condition with no specific clinical significance In doubtful cases, and particularly in members of a polyposis family, biopsy should be performed, but in the absence of other findings radiologic evidence of lymphoid hyperplasia would not appear to indicate extended or repeated examination, *neither justify* any aggressive or hazardous therapy

SUMMARY

A retrospective inspection of films from colon examinations revealed evidence of lymphoid hyperplasia in 24 of 229 infants and children The condition is more frequently demonstrated

demonstrated duodenal atresia and malrotation of the bowel Numerous small mucosal protrusions with umbilication suggesting lymphoid hyperplasia were visible in the entire colon (Fig 4) Entero-anastomosis was performed but no biopsy specimen was obtained

Discussion and Conclusions

Being based mainly on the number and size of lymph follicles in the large bowel the diagnosis of lymphoid hyperplasia must sometimes be uncertain Even on micro scopy any firm borderline between normal and hyperplastic lymphoid tissue would appear arbitrary and be difficult to define, particularly in a biopsy specimen Radiologic diagnosis has partly the same limitations and, in addition, depends on the examination procedure employed

The double contrast technique used at this department includes a post-evacuation film of the bowel taken between the first instillation of barium enema and the com bined administration of barium and air Lymphoid hyperplasia may occasionally be diagnosed on this post-evacuation film (Fig 2) or even with a conventional barium enema (Fig 4), but usually the condition has been far better demonstrated with double contrast examination The comparison made in the present review confirms that this procedure is the superior method for discovering the condition

It appears from the review that radiologic evidence of lymphoid hyperplasia of the bowel is a frequent finding in all ages of infancy and childhood Since far from all the examinations had been performed with optimum technique, the true incidence was probably even higher than that recorded Problems with the differential diagnosis and in managing the children with lymphoid hyperplasia therefore assume considerable practical importance

Disastrous consequences of mistaking lymphoid hyperplasia for malignant polyposis have been reported by COSENS (1958), by COLLINS et coll (1966) and by GRUENBERG & MACKMAN (1972) A similar mistake, though fortunately without such consequences, was initially made in our Case 2 As exemplified in Case 3 the hyperplasia may also occasionally be confused with ulcerative colitis In the present experience, however, the most common mistake has been to interpret the follicles as residual fecal matter adherent to the mucosa This simple fallacy is probably sufficient to explain why lymphoid hyperplasia in the past almost entirely escaped radiologic recognition

The radiologic criteria adopted for the present review are provisional and may require future modification The characteristic appearance of umbilicated protrusions described by CAPITANIO & KIRKPATRICK (1970) is an important distinguishing feature, which may prevent confusion not only with fecal matter but also with lesions such as ulceration or tumors However, it cannot be excluded with certainty that, in rare cases, multiple true tumors may assume a similar shape, and occasional coincidence between lymphoid hyperplasia in children—common as it is—and neoplasm or colitis should not be unexpected In fact, benign polyps coexisted with lymphoid

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INTUSSUSCEPTION IN THE NEWBORN INFANT

Report of a case

H JORULF and G SEDIN

Intussusception in the reonatal period is a rare condition RACHELSON et coll (1955) found that 0 3 per cent of 5 966 reported cases occurred during the first month of life TALWALKER (1962) described one personal case of intussusception in the neonatal period, reported 9 cases from other hospitals and selected 16 from the literature for review Sixteen of all these had symptoms and signs of intestinal obstruction or were given a diagnosis of intussusception during the first two days of life

The purpose of this report is to present a case of intussusception in a newborn infant diagnosed and reduced by barium enema

Case report

A boy, birth weight 2 470 g, was born of healthy parents after a gestational period of 38 weeks Because of a prolonged labour the baby was vacuum extracted The amniotic fluid contained large amounts of meconium After one minute an Apgar score of 5 and after five minutes a score of 8 was recorded The infant was pale and tachypnoic Inspection and palpation of the abdomen revealed nothing abnormal

Submitted for publication 23 February 1976

at double contrast examination than with the conventional barium enema Analysis of symptoms and signs and information obtained at follow-up suggests that this condition is usually, if not always, benign in childhood

ZUSAMMENFASSUNG

Die retrospektive Betrachtung von Filmen von Dickdarmuntersuchungen zeigten das Vorkommen von lymphoider Hyperplasie bei 24 von 229 Kleinkindern und Kindern Dieses Vorkommen ist bei Doppelkontrastuntersuchung haufiger nachweisbar als bei konventionellem Bariumeinlauf Eine Analyse der klinischen Symptome und die bei der Nachuntersuchung erhaltene Information deutet darauf hin, dass die Hyperplasie im Kindersalter gewohnlich, falls nicht immer, gutartig ist

RÉSUMÉ

Une etude rétrospective de films d'examens coliques a révélé des signes d hyperplasie lymphoïde chez 24 nourrissons et enfants sur 229 Cette affection est plus souvent mise en évidence par l'examen avec double contraste qu'avec le lavement baryté ordinaire L'analyse des signes fonctionnels cliniques et des signes physiques et les renseignements tirés de l'évolution ultérieure montrent que cette affection est habituellement, sinon toujours bénigne dans l'enfance

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Fig 1 a



Fig 1 b



Fig 2

Fig 1 Barium enema 38 hours after birth a) Intussusception in the ascending colon Barium is retained in the distal ileum from the follow through examination b) The intussusception is partly reduced

Fig 2 Post-evacuation film after reduction of the intussusception

Blood stained meconium was passed within 30 min after delivery Haemoglobin concentration fell from 149 g/l soon after birth to 113 g/l 9 hours later The thrombocyte count, thrombotest and activated thromboplastin time were within normal limits The body temperature was 39 4°C Laboratory findings indicated urinary infection Antibiotic therapy was instituted Bacteriologic cultures confirmed septicaemia

At 18 hours after birth conventional films of the abdomen demonstrated ordinary distribution of gas in the intestines A barium enema revealed an approximately 8 mm filling defect at the site of the ileocolic valve No barium passed into the ileum A follow-through examination was discontinued because of vomiting The bloody stools continued to pass The infant was pale, irritable and had an increased muscular tone, and the abdomen was distended Another barium enema was therefore given at 38 hours An intussusception was demonstrated in the ascending colon (Fig 1) A small amount of barium from the follow-through examination remained in the distal ileum proximal to the intussusception Following renewed attempts at hydrostatic reduction this was considered successful although no barium refluxed into the ileum as the contrast had disappeared on the postevacuation film (Fig 2)

Bloody stools continued for six days after reduction of the intussusception and blood transfusions were given repeatedly Six days after birth conventional films of the abdomen as well as a barium enema demonstrated nothing abnormal and the baby was discharged in good condition

Discussion

The symptoms and signs of intussusception in the newborn infant are intermittent crying, bile vomiting, bloody stools, abdominal distension and a palpable mass Passing of meconium has been observed in several cases

Five cases of intussusception during the first two days of life have been diagnosed at laparotomy (TALWALKER 1962) In occasional cases radiography of the abdomen has revealed intestinal obstruction Diagnosis by barium enema preoperatively has been established in one newborn infant by ÅKERRÉN & PETTERSSON (1954) and in one case by RACHELSON et coll (1955) The present case seems to be the first intussusception on record diagnosed during the first week of life by barium enema and reduced by hydrostatic pressure

In the material of intussusception in the newborn period collected by TALWALKER, the types were reported in 24 of the 26 cases as follows ileo-caecal (12) jejunal (8), ileal (3) and colic (1) Intrauterine intussusception has been described in occasional cases and may cause gangrene of the intestine resulting in atresia (LOUW & BARNARD 1955, PARKKULAINEN 1958, HOPFGARTNER & WURNIG 1973, TODANI et coll 1975) The aetiology in the present case is unknown However, an intrauterine asphyxia had occurred, possibly causing enhanced intestinal motility, which might be a contributory factor in intussusception

SPENCER (1969) has suggested that a combination of intestinal obstruction, palpable abdominal mass and bloody stools in the newborn infant should indicate volvulus with gangrenous bowel rather than an intussusception Also anal fissure and acute peptic ulcer are considered to cause rectal bleeding more often than intussusception in the newborn

In our opinion infants and children with signs of intestinal obstruction should have a diagnostic barium enema, if an intussusception is disclosed, hydrostatic reduction should be performed regardless of the duration of disease, the age of the infant and the location of the intussusception, except when peritonitis is present, indicating gangrene of the intestine (GIERUP et coll 1972)

To provide for an early diagnosis, the possibility of intussusception should be kept in mind in newborn infants with blood in the stools As in the present case this may be the only early sign indicating the diagnosis Moreover, persistent signs of intestinal obstruction in the newborn infant justify repeat radiography of the colon

SUMMARY

Report of a case of neonatal intussusception diagnosed and reduced by barium enema

ZUSAMMENFASSUNG

Beschreibung eines Falles von pranataler Invagination, die mit Bariumeinlauf diagnostiziert und reduziert wurde



Fig 1a



Fig 1b



Fig 2

Fig 1 Barium enema 38 hours after birth a) Intussusception in the ascending colon Barium is retained in the distal ileum from the follow through examination b) The intussusception is partly reduced

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HEART VOLUME AND HAEMATOCRIT VALUE FOLLOWING AORTO-PULMONARY ANASTOMOSIS IN CHILDREN WITH FALLOT'S ANOMALY

W MORTENSSON, N -R LUNDSTRÖM and T H OLSSON

The most severe effects of Fallot's anomaly are related to arterial hypoxaemia caused by intracardiac right-to-left shunt and pulmonary hypoperfusion To reduce these effects, an extracardiac shunt between the pulmonary and the systemic circulation is still applicable in certain circumstances The procedure is used only as a palliative in anticipation of total repair of the malformation Its effect on arterial hypoxaemia is related to the volume of blood shunted, as is also the appearance of complications such as left-heart failure

The extracardiac left-to-right shunt may cause enlargement of the left heart and the increased pulmonary blood flow may cause widening of the pulmonary vessels These changes form the basis for the conventional roentgenologic examination of shunt function

Heart size ha[illegible]
performed by [illegible]
GLENN (1958 [illegible] changes in heart volume may be used as a parameter to check the effectiveness of the shunt (PERKINS et coll 1949, CAMPBELL 1958, PAUL et coll 1961, WALZEM & SINGLETON 1963, KAPLAN et coll 1968) Irrespective of the operation

Submitted for publication 4 August 1975

RÉSUMÉ

Présentation d'un cas d'invagination intestinale néo natale diagnostiquée et reduite par lavement baryté

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Table

Heart volume index immediately before shunt operation and changes 2 months 1 year and 2 years postoperatively Haematocrit value was measured at the same periods and expressed in per cent Increase (+) or decrease (−) in HVI is given in relation to the preoperative value

Case No	Heart volume index				Haematocrit value			
	Preop	Postoperatively			Preop	Postoperatively		
		2 months	1 year	2 years		2 months	1 year	2 years
1	93	162	+40	+15	55	—	40	43
2	110	—	+40	+20	63	38	38	43
3	115	50	5	−10	48	48	54	55
4	93	+ 50	+85	+90	61	48	40	41
5	87	+ 44	+13	+13	59	50	46	47
6	85	0	+15	5	59	48	50	52
7	105	+ 35	+15	+15	66	42	50	—
8	91	+ 27	−37	+46	45	45	44	40
9	108	− 8	20	28	59	47	53	55
10	92	+ 56	+98	+60	58	40	41	41
11	85	+ 25	60	+30	63	47	45	45
12	82	+ 38	—	+36	70	48	46	48
13	117	+ 70	+33	+63	59	35	36	34
14	93	− 14	0	10	67	44	49	51
15	90	+ 75	+22	+46	48	35	—	41
16	108	+ 51	+42	—	58	42	40	—
Mean values	97	− 47	−32	+25	58	44	45	45

(HVI) The volumes were calculated by two of the authors together and compared with the original reports

The haematocrit value was determined from a capillary blood sample

The follow up period was one year in one patient and more than 2 years in the others Measurements made at 4 different periods are reported, namely those made immediately preoperatively and those made about 2 months and one and 2 years postoperatively However determinations of heart volume or haematocrit value are missing on some occasions (Table)

Results

Postoperative changes in HVI were usually associated with inverse alterations in haematocrit value (Table)

Two months after operation, no significant correlation was found between the changes in HVI and those in the haematocrit value In 3 cases (Nos 6, 9, 14) with no or only slight increase in HVI, the haematocrit value decreased initially but later

method used, an average increase of 10 per cent in the cardio-thoracic ratio was noted (CAMPBELL, BAKER et coll 1949), and an increase of 6 to 30 per cent in the heart volume (MÖLLER 1962) The increased heart size appeared already in the first months following operation However, the size may be unchanged in spite of clinical improvement

Anastomosis between the ascending aorta and the right pulmonary artery by the method of WATERSTON (1962) has been used to an ever increasing extent in surgery in infants and small children The advantages of this method are that a satisfactory flow may be achieved also in cases with small vessels, and that the anastomosis is easily closed at the time of total correction of the heart disease However, a drawback that this method has in common with Potts' anastomosis is the fairly great risk of shunting too large a blood volume and of the development of pulmonary hypertension (JONES et coll 1969, BERNHARD et coll 1971, PICKERING et coll 1971, REITMAN et coll 1974) The unfavourable effects of the Waterston anastomosis were recently analysed (TAY et coll 1974)

SOMMERVILLE et coll (1969) found that the heart volume increased following the Waterston anastomosis but the degree of increase was not stated nor were these effects compared with other effects of the shunt WALDHAUSEN et coll (1968) reported only a small increase in heart volume postoperatively, even in patients with definite heart failure

The arterial hypoxaemia in patients with Fallot's anomaly evokes a polycythaemic response which, in general, is directly proportional to the degree, duration and continuity of the anoxic stimulus, as demonstrated in normal individuals by HURTADO et coll (1945)

Whether or not a correlation exists between changes in heart volume and in the haematocrit value in children with Fallot's anomaly following the Waterston anastomosis has been analysed, as well as to what extent changes in heart volume reflect the function of the shunt

Material and Methods

The material comprised 16 children with Fallot's anomaly and hypoxaemia and polycythaemia The diagnosis was confirmed at angiography In all children the method of Waterston was employed a communication between the right branch of the pulmonary artery and the ascending aorta was established Repeat heart catheterization and cardioangiography were performed 2 to 4 years after operation in 14 of the patients

The age of the patients at the time of operation varied between 2 months and 7 years and 1 month, the median age being 3 years

The heart volume was assessed by the method of JONSELL (1939) The volume per m^2 of body surface was expressed in per cent of the mean value for healthy children of corresponding age (LIND 1950), this ratio is referred to as the heart volume index

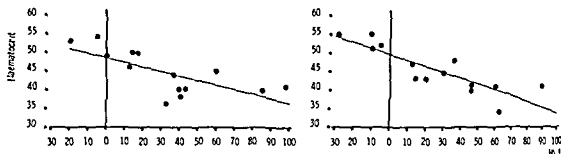
In one patient (No 11), a decrease in HVI was observed during the second year after operation The decrease progressed in the following months and the haematocrit value rose, two and a half years after the operation, angiography demonstrated occlusion of the right pulmonary artery This artery was normal in the remaining six cases and on angiography the function of the anastomosis was considered to be satisfactory, angiography was not performed after operation in Cases 15 and 16

The greatest increase in HVI (160) was recorded in a patient who also developed left heart failure She was treated conservatively, after some months there was no evidence of heart failure and, at the same time, HVI decreased (Case 1) In 2 other children (Nos 10, 13), with increase in HVI of +70 to +80, left heart failure also appeared In 4 additional patients (Nos 4, 11, 15, 16), the increase in HVI exceeded +50 at one or several examinations These patients did not have clinically manifest heart failure However, one of these (No 10) was treated with digitalis as a preventive measure and another child (No 15) was affected by a postcardiotomy syndrome

Discussion

It is reasonable to assume that variation in heart volume reflects mainly the effect of the shunted blood volume on the left heart and the capacity of the heart to manage this increased volume The haematocrit value should reflect the state of arterial anoxaemia according to HURTADO et coll (1945), and thus also depends on the function of the anastomosis A fairly good correlation was found between late postoperative changes in HVI and the actual level of the haematocrit value However, during the first months following operation no such correlation was present, probably because the time lapse was too short for the organism to adapt to the new conditions A postcardiotomy syndrome may also contribute to heart enlargement at this period Signs such as fever and elevated ESR indicate the possible existence of this condition Absence of, or weak correlation between changes in HVI and absolute or relative variations in the haematocrit value depend on the fact that the higher the preoperative haematocrit value, the greater was the subsequent reduction This implies that with marked polycythaemia even a small shunt with almost no haemodynamic effect may have a favourable, albeit not optimum, effect on the hypoxaemic state and thus on the haematocrit value

When the shunted blood volume was large enough to cause an increase in HVI of about +20 to +40, an optimum effect on the haematocrit level was observed A greater increase in HVI probably means that there was a considerable load on the left heart, even if this did not necessarily result in manifest heart failure These findings agree with the results of PAUL et coll (1961) in children operated upon according to the method of POTTS In their report a significant correlation existed between increase in pulmonary blood flow and arterial oxygen saturation, when the flow increase was at most a doubling of the preoperative flow volume, when the flow in-



The haematocrit values (per cent) related to postoperative changes in heart volume (HVI) one year (left) and 2 years (right) after Waterston operation Formulas for the regression line $y = -0.12x + 48.7$, $r = -0.71$, $p < 0.01$, and $y = 0.16x$ 49.58 $r = 0.85$, $p < 0.001$, respectively

increased, angiography demonstrated that partial occlusion of the anastomosis had occurred Otherwise, at this time changes in HVI did not indicate the future development of the function of the anastomosis or the capacity of the left heart to accommodate to the load of the shunt

One year after operation, the correlation between the changes in HVI and the *absolute changes* in haematocrit value (= preoperative value minus postoperative value) was low and not significant Two years after operation a significant, although still low, correlation was found (correlation coefficient $r = -0.63$, $p < 0.05$)

The correlation between the changes in HVI and the *relative variations* in haematocrit value (= the ratio of postoperative to preoperative haematocrit values) was also low, one year as well as 2 years after operation (r 0.54, p 0.05 and $r = -0.68$, $p < 0.05$, respectively)

The correlation between the changes in HVI and the *actual level* of haematocrit value was fairly good, both one and 2 years after operation (Figure) Fifty and 73 per cent, respectively, of the variations in the haematocrit value could be explained by variations in HVI

An increase in HVI of +25 or more present at one or 2 years after operation, was invariably associated with a decrease in haematocrit value to 45 per cent or less (Figure)

Two years after operation, HVI was lower than in the preoperative period in 4 patients and the haematocrit value was high (Nos 3, 6, 9, 14) Total or subtotal occlusion of the anastomosis and the right pulmonary artery was later demonstrated at angiography In 3 other patients, HVI was about +15, but the haematocrit value varied and corresponded to the angiographic findings in Case 1 the function of the anastomosis was satisfactory, in Case 5 the proximal part of the right pulmonary artery was slightly compressed but the flow through thean astomosis was considered to be unaffected, and in Case 7 the blood flow through the anastomosis was reduced and, in addition, pulmonary branches to the right upper pulmonary lobe were partly occluded

du volume cardiaque a été corrélée avec la valeur de l hématocrite Dans 14 de ces cas, la fonction de l anastomose a aussi été étudiée par cardioangiographie Les mesures de volume du coeur en série ont été utiles pour apprécier le fonctionnement de l'anastomose

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crease was greater, only an insignificant further increase in arterial oxygen saturation occurred

When the increase in HVI is slight during the first months following operation, this would seem to predict poor function of the anastomosis in the future, in spite of a satisfactory initial response in the haematocrit value At a later stage, a slight increase in HVI was found to be compatible with various haematocrit values and the function of the shunt Although a decrease in HVI usually occurred at the same time as the haematocrit value increased, *partial occlusion of the anastomosis was not predictable until HVI* was lower than the preoperative value The occlusive abnormalities may have affected not only the anastomosis but also the right branch of the pulmonary artery

A considerable element of subjectivity is inherent in assessment of the pulmonary vessels (WEITZMAN et coll 1974) The results of such an assessment are therefore not *presented in this report However, when the increase in HVI was 50 or more*, and only then, chest examination disclosed a distinct widening of the intrapulmonary vessels as compared with the preoperative condition and in the right lung only Heart volume determination is more accurate and at repeated determinations in children the error of the method was 3 to 5 per cent (AXÉN & LIND 1945, LIND 1950) In the present material, changes in the heart volume after the shunt operation seem to agree with those previous reports giving precise statements of the preoperative heart volume changes

It may be concluded that repeated heart volume measurements will aid in the evaluation of the function of the Waterston anastomosis, too large a shunt as well as the appearance of occlusion of the anastomosis will be revealed

SUMMARY

In 16 children with Fallot's anomaly and Waterston anastomosis, the effect of the shunt was examined repeatedly up to 2 years after operation Change in heart volume was correlated with the haematocrit value In 14 of the cases the function of the anastomosis was also evaluated on cardioangiography Serial heart volume measurements were found useful to evaluate the function of the anastomosis

ZUSAMMENFASSUNG

Bei 16 Kindern mit einer Fallotschen Anomalie und einer Waterstonschen Anastomose wurde der *Effekt des Shunts wiederholt bis zu 2 Jahren nach der* Operation untersucht Änderungen im Herzvolumen wurden zum Hämatokritwert korreliert In 14 der Falle wurde auch die Funktion der Anastomose mit Kardioangiographie untersucht Serienmessungen des Herzvolumen zeigten sich als Wertvoll um die Funktion der Anastomose abzuschatzen

RÉSUMÉ

Chez 16 enfants atteints d anomalie de Fallot avec anastomose de Waterston l effet du shunt a été examiné à plusieurs reprises jusqu'à 2 ans après l'opération La modification

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SPINAL CORD VASCULARITY

V The venous drainage of the spinal cord in the rat

LEON TVETEN

Blood from the interior of the spinal cord drains through an extensive venous plexus in the pia mater which communicates with the pial veins around the brain stem From this plexus and from longitudinal trunks on the ventral and dorsal surfaces of the cord radicular veins follow the nerve roots and empty into the epidural venous plexus These veins have no valves and communicate freely with the intracranial sinuses in the posterior fossa and at all levels with the inferior vena cava, the azygos and hemiazygos veins through the vertebral veins in the intervertebral foramina

Reports on the anatomy of the spinal cord veins are scanty compared with those of the arteries, both in man and experimental animals The first descriptions in man are from KADYI (1889) and later TUREEN (1938), HERREN & ALEXANDER (1939) and SUH & ALEXANDER (1939), who reported that the arrangement of the spinal cord veins corresponded to a large extent with that of the arteries More recently (CLEMENS & QUAST 1960, LAZORTHES et coll 1962, QUAST 1962, JELLINGER 1966, GILLILAN 1970), however, differences were found in the two vascular systems, the same applies to the few accounts on experimental animals such as the cat and the rabbit (JELLINGER), the guinea pig (COIMBRA 1957) and the rat (WOOLLAM & MILLEN 1958) Unfortunately, the short description of the latter authors is not sufficiently detailed for

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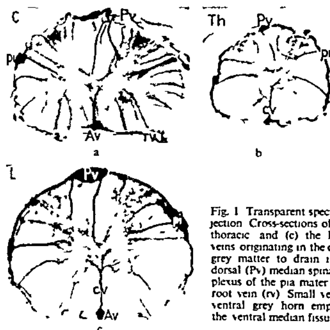


Fig. 1 Transparent specimen photography venous in jection Cross-sections of (a) the cervical (b) the middle thoracic and (c) the lumbar region Intramedullary \eins originating in the center or at the periphery of the grey matter to drain into the ventral (A\) and the dorsal (P\) median spinal \eins and also into the \enous plexus of the pia mater (pi) Central \ein (c\) \entral root vein (rv) Small \ein from the medial part of the \entral grey horn emptying into the central \ein in the ventral median fissure (b) (—►) (× 13)

The central venous system

The medial portions of the ventral grey matter and the white matter along the ventral median fissure drained mainly through \enules con\erging towards the \entral white commissure to form central veins (Fig 1) Thus, contrary to the supply arrangement of the central artery (TVETEN 1976 d), the central \ein drained both sides of the cord Additional short venules from the white matter along the \entral median fissure and occasionally also from the \entro-medial part of the ventral grey horn drained directly into central veins in the ventral median fissure (Fig 1 b) The central \eins were more numerous but smaller in size than the corresponding arteries They traversed the fissure in a slightly winding course, often interconnecting before they terminated into the ventral median spinal vein No significant connections existed between adjacent central veins within the substance of the spinal cord

The peripheral venous system

Veins reaching the \entral and the lateral surfaces of the cord arose mainly in the center or at the border of the ventral and lateral grey horn They zigzagged through the white matter more or less in the \ertical plane Similarly, veins from the dorsal grey horn terminated into the pial plexus on the dorsal surface of the cord while the dorsal white matter drained mainly into the dorsal median spinal vein by way of conspicuous vessels originating near the dorsal grey commissure (Fig 1)

No connections between the [illegible] 'es could be found within the cord

experimental use of the rat, especially with regard to the arrangement of intramedullary veins

Previous reports have pointed out the similarity between the arterial supply of the spinal cord in man and rat (TVETEN 1976) The present investigation concerns the venous drainage of the spinal cord — particularly the arrangement of the intraspinal veins with the purpose of creating a rationale for the use of rats in experiments on vascular myelopathies

Material and Methods

Eighteen young and adult rats of both sexes, randomly selected, were used The body weights ranged between 150 and 350 g In 10 of the animals both arteries and veins in the spinal cord were filled with a coloured contrast medium by the method previously described (TVETEN 1976 b) In 5 adult rats a filling of the extra- and intraspinal veins only was obtained by a modification of the method described by BOWSHER (1954) two weeks before injection of the contrast medium the vena azygos was ligated operatively at its junction with the superior vena cava The thoracotomy was performed in the third left intercostal space under positive pressure anaesthesia as previously described (KLUGE & TVETEN 1968) This operation is known to result in reversed blood flow in the vena azygos system with enlargement and hypertrophy of the main vein and its tributaries (BOWSHER) Three animals did not survive the immediate postoperative period and were excluded from the material

About 30 min before injection of the contrast medium, heparin was administered into the peritoneal cavity in order to facilitate the flow of the contrast medium suspension The chest was then opened and a polyethylene catheter with a calibre as coarse as possible was introduced into the upper part of the vena azygos A 20 per cent warm (37 to 38°C) aqueous suspension of the coloured contrast medium Chromopaque Blue (Damancy & Co Ltd , England) containing 4 % formalin and 10 % gelatine was injected slowly into the catheter Two or three ml of the contrast suspension was sufficient to fill the intra- and extraspinal veins

Following the injection the specimens were prepared and made transparent by the method previously described (TVETEN 1976 b)

Whole specimens and segments of the spinal cord cut in the transverse or longitudinal planes were examined by stereomicroscopy in different positions with the specimens submerged in oil of wintergreen beneath a binocular microscope

Results

The venous drainage of the spinal cord parenchyma may be divided into a central and a peripheral venous system The former includes veins within the cord emptying via the central or sulcus veins into the ventral median spinal vein, while the latter comprises veins draining into the venous plexus of the pia mater and the dorsal median spinal vein

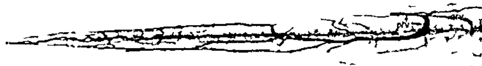


Fig 3 Transparent specimen, photography, venous injection Dorsal view of the lumbo-sacral cord The great dorsal radicular vein (prv) and the dorsal median spinal vein (Pv) The great ventral radicular vein (arv) branching from the ventral median spinal vein (Av) is demonstrated (× 5)

in the posterior fossa (Fig 2 b) Caudally, the vein was formed by relatively large tributaries crossing the lateral and dorsal surfaces of the cord (Fig 3) It drained most of the dorsal white matter and received branches from the dorsal and lateral pial plexus At different levels the ventral and dorsal median spinal veins gave off a radicular vein along the ventral and dorsal nerve roots, respectively

Two smaller longitudinal trunks were invariably observed on the dorso-lateral surface of the cord running along the dorsal nerve rootlets (Fig 2 a) These trunks drained mainly the dorsal grey horns but connected also lavishly with the pial veins

The venous plexus of the pia mater was constituted by an abundance of small and relatively large, transverse or oblique branches (Figs 2, 3) Some of these encircled the cord interconnecting the ventral and the dorsal median spinal veins (Fig 2) The pial veins drained most of the ventral and lateral white matter, in addition to parts of the ventral, lateral and dorsal grey matter (Fig 1)

The radicular veins following the ventral nerve roots were formed by branches from the ventral median spinal vein and twigs from the ventro-lateral pial venous plexus They varied considerably in size and position and were not related to the root arteries The veins following the dorsal roots were usually larger receiving tributaries from the dorsal median spinal vein and the dorso-lateral pial plexus

One of the ventral and dorsal radicular veins was invariably larger in size than the others and was usually situated in the lower thoracic or upper lumbar region (Fig 3) The position of these veins was not related to the great ventral radicular artery of Adamkiewicz

The radicular veins joined the segmental vertebral veins in the intervertebral foramina or emptied into the large epidural venous plexus The latter communicated with the venous sinuses of the posterior fossa (Fig 4), in the cervical region with the vertebral vein in the thoracic region with the vena azygos (Fig 5) and hemiazygos, and in the lumbosacral region with the inferior vena cava and the pelvic venous plexus

Discussion

Bowsher, in his comparative anatomic investigation in man and several laboratory animals including the rat, stressed the importance of the connection of the vena azygos system with the internal vertebral venous system, but gave no account of the

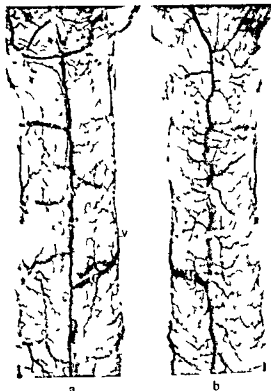


Fig 2 Transparent specimen, photography venous injection (a) Ventral and (b) dorsal aspect of the cervical cord division of the ventral (Av) and the dorsal (Pv) median spinal veins at the lower border of the brain stem (→) Lateral vein (Lv) Large trunks (tr) at the circumference of the cord interconnecting the two veins (× 5)

The size of the intramedullary veins varied considerably, and not infrequently some of the veins in the dorsal and lateral white matter were as prominent as those draining through the ventral median fissure (Fig 1)

The surface veins of the spinal cord

These include the venous plexus of the pia mater and two large venous trunks, the ventral and the dorsal median spinal veins

The ventral median spinal vein was located in the ventral median fissure just dorsal to the ventral spinal artery Rostrally, the vein usually bifurcated to join the venous plexus on the ventral surface of the brain stem (Fig 2 a) Caudally, it tapered off at the conus medullaris The vessel varied somewhat in size in different parts of the spinal cord, being markedly smaller than the ventral spinal artery and also than the dorsal median spinal vein Short breaks in the ventral median spinal vein were occasionally observed In addition to the supply from the central veins, it received branches from the ventral and lateral pial venous plexus and also gave rise to radicular veins which joined the ventral nerve roots

The dorsal median spinal vein was a conspicuous trunk on the dorsal surface of the spinal cord coursing close to the dorsal median sulcus At the lower border of the brain-stem it usually divided into two branches joining the pial venous plexus

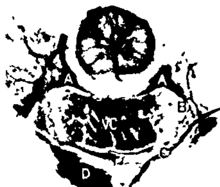


FIG 5 Transparent specimen, photography, venous injection Cross-section of the middle thoracic region of the vertebral column (VC) with intact spinal cord, venous drainage from the epidural venous plexus (A) via the intervertebral (B) and the intercostal (C) veins to the vena azygos (D) (× 5)

material However, the degree of filling also depends on other factors such as the injection pressure and the viscosity of the injected medium

In animals subjected to retrograde injection of the veins no evidence of filling of the capillary plexus was obtained SUH & ALEXANDER as well as GILLILAN also comment on the lack of capillary filling following retrograde injection of the large venous trunks on the surface of isolated human cords SUH & ALEXANDER believed that a monocuspid valve at the point of junction between the veins of the third and the fourth order prevented filling of the second-order branches (precapillary venules) and the capillaries This valve was considered to be a rudder-like prolongation of the wall of the vein at the inner angle of bifurcation protruding back into the lumen of the common vessel Since the length of the valve exceeded the diameter of the vessel it was assumed to prevent regurgitation of blood GILLILAN confirms the presence of a rudder-like structure of the wall at the junction of two terminal venules since they meet at a very narrow angle, but on the basis of histologic sections claims that it is never greater in length than the diameter of the larger vein However, the mechanism preventing the flow of injected medium from veins to capillaries has not been elucidated

The appearance of the intramedullary veins with venules meeting at acute angles and their characteristic zigzag course through the white matter and the ventral median fissure facilitated the identification of veins versus arteries in completely injected spinal cords

In accordance with more recent investigations in man (JELLINGER, GILLILAN) and some experimental animals (for ref see JELLINGER) the present results demonstrate that the anatomic arrangement of the spinal cord veins is different from that of the arteries in the rat The results obtained also lend support to the view that true venae concomitantes do not occur within or on the surface of the cord Contrary to the arterial supply, the blood from the cord was found to drain through radially arranged veins to the peripheral surface of the spinal cord

GILLILAN stated that a distinct gap was present on the lateral surface of the cord

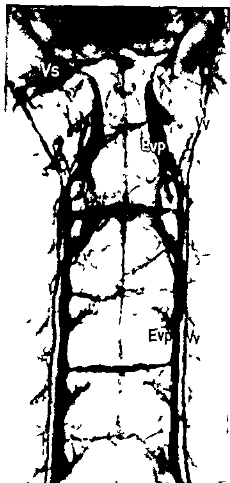


Fig 4 Transparent specimen, photography, venous injection Dorsal view of the cervical region the vertebral vein (Vv) and the epidural venous plexus (Evp) connecting with the venous sinuses (Vs) of the posterior fossa (→) (×5)

spinal cord veins He also reported that filling of the epidural venous plexus in rodents was difficult to achieve by injecting the azygos vein under normal conditions, which agrees with the present preliminary experiments In these experiments it was also found that injections into other extraspinal veins such as the inferior and the superior vena cava failed to fill the intraspinal vessels both in rats and in stillborn human infants These observations support the conclusions by BOWSHER that there is a valve in the vein of the intervertebral foramen either at its junction with the posterior intercostal vein or at its point of union with the epidural venous plexus

CLEMENS and OSWALD (1961) assumed the presence of a second valve at the point of union between the radicular vein and the epidural venous plexus preventing regurgitation of blood into the root vessels Unfortunately, the exact site of such valves could not be determined in the present series of experiments

It is well known that obstruction of a major venous trunk may lead to functional disturbances of the valves due to altered haemodynamics and dilatation of the vessel Such alterations following ligature of the vena azygos may explain the successful filling of the spinal cord veins and the vertebral plexus obtained in the present



Fig 5 Transparent specimen photography, venous injection Cross section of the middle thoracic region of the vertebral column (VC) with intact spinal cord, venous drainage from the epidural venous plexus (A) via the intervertebral (B) and the intercostal (C) veins to the vena azygos (D) (× 5)

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GILLILAN stated that a distinct gap was present on the lateral surface of the cord

between the ventral and the dorsal half of the pial venous plexus, i e about halfway between the ventral and the dorsal nerve rootlets However, SUH & ALEXANDER as well as CLEMENS & QUAST, described and depicted large pial veins crossing the lateral surface of the human cord to connect the anterior and the posterior pial veins

In the present material of rats, it was found, as GILLILAN observed in man, that the pial venous plexus was best developed on the ventral and the dorsal surface of the cord but larger veins crossing the lateral surface of the cord of the rat were not infrequently observed These veins interconnected the ventral and the dorsal median spinal veins and received tributaries from the dorsal as well as the ventral pial plexus Thus, a separation of the pial venous plexus into two independent systems in the rat found no morphologic support

As in man, the size and location of the radicular veins in the rat were unrelated to that of the arteries SUH & ALEXANDER, as also GILLILAN, described a vena radicularis magna anterior in the low thoracic or upper lumbar cord in man In rats a dorsal radicular vein more prominent than its ventral counterpart was found both usually leaving from the upper part of the lumbar enlargement

The existence of venous anastomoses within the spinal cord has been a matter of some dispute GILLILAN described *intersegmental anastomoses* between veins in the grey matter, lateral to the central canal Later, however, on discussing the venous anastomoses observed by SUH & ALEXANDER she surprisingly concluded that 'although the capillary plexus within the spinal cord constitutes an anastomotic system at the capillary level, there is little or no evidence of intrinsic venous anastomoses' Nevertheless, this statement concurs with the present findings and it was believed that venous anastomoses occasionally described by KADYI as well as SUH & ALEXANDER in man and also those observed in the guinea pig by COIMBRA most probably represent incidental findings

In conclusion the results of the present work suggest a close similarity in the anatomic arrangement of the spinal cord venous system in man and rat In both of them the appearance of the intrinsic and extrinsic spinal cord veins are different from that of the arteries Thus, in creating experimental vascular myelopathy in the rat, it should be possible to differentiate between lesions of venous and arterial origin

SUMMARY

The anatomy of the spinal cord venous system has been investigated by stereomicroscopy in rats subjected to arterial or venous injections of a coloured contrast medium The results demonstrate the arrangement of the intrinsic and the extrinsic spinal cord veins to be different from that of the arteries, a feature consistent with previous descriptions in man An exact knowledge of the venous anatomy is considered essential in evaluating the origin of experimental vascular lesions associated with impaired spinal cord circulation

ZUSAMMENFASSUNG

Die Anatomie des venosen Systems des Ruckenmarks wurde mit Hilfe von Stereomikroskopie bei Ratten denen arteriell oder venos ein gefarbtes Kontrastmittel injiziert worden war, untersucht Die Ergebnisse zeigen, dass der Aufbau der inneren und äusseren Venen des Ruckenmarks unterschiedlich ist von dem der Arterien, einem Verhalten, das mit dem fruher am Menschen beschriebenen ubereinstimmt Die genaue Kenntnis der venosen Anatomie wird fur die Bewertung des Ursprungs von experimentellen vaskulären Läsionen, verbunden mit einer beeinträchtigten Zirkulation des Rückenmarks, als wesentlich hervorgehoben

RÉSUMÉ

L anatomie du système veineux de la moelle epinière a été étudiée chez le rat par stereomicroscopie apres injection artérielle ou veineuse de moyens de contraste colorés Les resultats montrent que la disposition des veines médullaires intrinsèques et extrinseques est différente de celle des artères, caractère qui concorde avec les descriptions deja faites chez l homme L auteur considere qu'une connaissance exacte de l anatomie veineuse est essentielle pour determiner l origine de lesions vasculaires expérimentales associées à un trouble de la circulation de la moelle

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FROM UNIDAD DE NEUMOLOGIA, HOSPITAL GENERAL S S A , MEXICO, MEXICO

LYMPHATICS OF THE DIAPHRAGM IN THE DOG

O RIVERO and H DEL CASTILLO

The previous knowledge of the anatomy of the lymphatic system has been widened by radiology, which allows not only a demonstration of the morphology but also of the lymphatic circulation, thus explaining or elucidating phenomena such as the lymphatic dissemination of neoplasms and infections, as well as collateral pathways in occlusion of lymphatics

Attempts have been made to determine the lymphatic circulation by means of dyes which are photographically or cinematographically traced, but the main contribution to this extended knowledge has been made by radiology, using contrast media (CELIS & KUTHY 1952)

Radiology of the lymphatic system has two main objects, first to display the morphology of the ducts, their anastomoses and the direction of the circulation, and secondly to demonstrate the various nodes with their afferent and efferent lymph vessels (CELIS et coll 1956)

The exploration of the lymphatic system discovered by RUDBECK (1653, 1654), was facilitated by the method introduced by NUCK already in 1692 He used mercury as a colouring agent on human and animal corpses The lymph vessels of the diaphragm and the inner surface of the thorax were described by SAPPEY (1874) A detailed anatomic description of the lymphatic system before the radiologic era was given by BARTELS (1909)

As the radiologic appearance of the lymphatic system of the diaphragm is less

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Fig 1



Fig 2

Fig 1 The main diaphragmatic duct and its connection to the internal mammary ducts

Fig 2 Internal mammary ducts and a constantly filled node at the superior end of the sternum

well known, animal experiments were performed in an attempt to demonstrate its morphology and circulation The results are now reported

Material and Method Thirty-five mongrel dogs were used A low thoracotomy at diaphragmatic level was performed under controlled endotracheal anaesthesia in 30 cases on the right side and in 5 on the left

In the first 10 cases Evans blue was injected into the diaphragmatic muscle fibers This dye passed into the lymphatic channels of the diaphragm and coloured the main ducts, allowing observation of the lymph flow In the next 10 cases, Evans blue was mixed with Lipiodol Ultra Fluid warmed to 36°C and films were obtained at 10-min intervals during the first hour and then 1 h later The following 10 dogs were examined by means of a Zeiss surgical microscope with ten fold magnification and using microcannulas specially designed for the lymphatic system One of the main lymphatic ducts in the right diaphragm was cannulated and contrast medium mixed



Fig 3



Fig 4

Fig 3 Para aortic abdominal node filled through a narrow duct from the main diaphragmatic duct

Fig 4 Cannulation of the diaphragmatic lymphatic Double interna mammary ducts

with Evans blue was injected under visual control Films were exposed with the same time sequence In the remaining five dogs the same experiments were performed on the left hemidiaphragm

Results

As the diaphragm is a thin muscle, some difficulties were encountered in the first attempts to inject the contrast medium Immediately following injection Evans blue was visible in the network of diaphragmatic lymphatics and passed rapidly into the efferent ducts along the internal mammary arteries and veins When the dye mixed with contrast medium was deposited in the diaphragm, radiology demonstrated rapid filling of ducts and nodes as follows (1) a main diaphragmatic duct passed through the muscle in a postero-anterior direction (Fig 1), (2) this duct received branches from various diaphragmatic areas (3) it passed on to the lym-



Fig 5



Fig 6



Fig 7

Fig 5 Lymphatic plexus above the retrosternal node

Fig 6 Demonstration of left diaphragmatic lymphatic Double internal mammary ducts and parasternal nodes

Fig 7 Ascending paracardiac mediastinal channel and mediastinal node

phatic internal mammary chain as a single or double retrosternal channel ending at the upper end of the sternum, where one or several nodes were constantly present at the parietal pleura (Fig 2), (4) in 2 cases the contrast medium passed from the postero-anterior main duct through a narrow duct to a para-aortic abdominal node (Fig 3) and in 3 cases a central mediastinal branch was filled, which ended in a tracheobronchial node

Similar findings were obtained when the coloured contrast medium was injected directly into a diaphragmatic lymphatic duct However, the following differences were observed (1) the lymphatics of the diaphragm were more clearly visible, (2) in all cases two branches following the internal mammary vessels were filled (Fig 4), (3) beyond the upper retrosternal node a lymphatic plexus was filled, apparently emptying into the great thoracic vein or the thoracic duct (Fig 5)

On the left side the main postero-anterior diaphragmatic duct was similar to that observed on the right side ending in the internal mammary chain (Fig 6) In 2 of these 5 cases an ascending paracardiac mediastinal duct was filled, which ended in a mediastinal node (Fig 7)

Discussion

The results obtained by cannulating a diaphragmatic lymphatic duct were superior to those obtained by injecting contrast medium into the diaphragmatic muscle With the present microsurgical technique and fluoroscopy with an image intensifier, direct lymphography by cannulating is to be preferred whenever possible

The existence of a main diaphragmatic duct was evident and the lymphatic flow was directed postero anteriorly The rapid filling of the efferent duct with its internal mammary connection and its outlet into the blood through the great thoracic vein or the thoracic duct explain the systemic repercussion of infectious processes even if located at the base of the pleura Once the upper retrosternal lymphatic node and the lymphatic plexus had been filled, the contrast medium appeared to flow almost directly into the venous circulation In all these cases the outlet was located close to the subclavian vein

When contrast medium was injected by lymphatic cannulation, two internal mammary ducts were filled on each side If this were the case also in man, it means that the mammary lymphatic channels are two instead of one as previously stated

The injection into the main duct of the right diaphragm filled an ascending mediastinal duct in one case only, contrary to the condition on the left side where such a duct was filled in 2 of 5 cases

The internal mammary ducts receive flow from visceral and peritoneal lymphatic ducts at subdiaphragmatic level, resulting in an ascending communication between subdiaphragmatic lymphatics and the main diaphragmatic duct This may explain the inflammatory reaction of the pleura in hepatic or other subphrenic processes, as well as neoplastic dissemination to the pleura from subdiaphragmatically located malignancies



Fig 5



Fig 6



Fig 7

Fig 5 Lymphatic plexus above the retrosternal node

Fig 6 Demonstration of left diaphragmatic lymphatic Double internal mammary ducts and parasternal nodes

Fig 7 Ascending paracardiac mediastinal channel and mediastinal node

FROM THE DEPARTMENTS OF RADIOLOGY AND ENDOCRINOLOGY, MEDICAL ACADEMY, POZNAN, POLAND

ABNORMAL BASAL ANGLE OF THE SKULL IN SEX CHROMOSOME ABERRATIONS

K. RZYMSKI and J. KOSOWICZ

The base of the skull develops from cartilage and is one of the most stable parts of the skull. In healthy subjects the angle of the base does not change from the third year of life to adulthood (BERGERHOFF & STILZ 1954). In 99 per cent of skull films the angle measured 131 to 135°. The small variations of the angle are probably related to the fact that the base is connected with the size of the brain stem, which is the most constant part of the brain; it is not influenced even by gross skull deformities such as macrocrania or microcrania (DORST 1964).

The angle of the base of the skull has been measured in sex chromosome aberrations and hormonal disorders with pertinent radiologic abnormalities of the skull, and the result is now reported.

Material and Methods

Measurements of the basal angle were performed on lateral skull films. This angle is formed by the intersection of two lines running through the base of the nose (nasion), the tubercle of the sella turcica, and the anterior border of the foramen magnum (basion). Films of the skull were taken in the following sex chromosome aberrations: Turner's syndrome (53 cases), Klinefelter's syndrome (23 cases), XYY syndrome (3 cases), and XXX syndrome (1 case).

The patients with Turner's syndrome, aged 7 to 51 years, had typical clinical

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On injecting the diaphragmatic lymphatics, the internal mammary collectors were never filled in a descending direction Only in 2 cases was a para-aortic sub diaphragmatic node filled from the main diaphragmatic channel through a narrow duct In no case was a descending flow in the mammary chain observed This would explain why pleural or pleuropulmonary infections or neoplasm seldom extend into the subdiaphragmatic region

SUMMARY

Lymphography of the diaphragm was performed in 35 dogs A main diaphragmatic duct passed in a postero-anterior direction, receiving several branches from the diaphragm It passed to a double mammary internal channel ending at the upper end of the sternum where a group of nodes were constantly present, and beyond this a lymphatic plexus was filled

ZUSAMMENFASSUNG

Eine Lymphographie des Diaphragmas wurde bei 35 Hunden vorgenommen Ein Hauptstamm des Diaphragmas lief in posterio-anterior Richtung, der verschiedene Äste des Diaphragmas erhielt Dieser lief durch einen doppelten Kanal der internen Mamma Arterie und endete im oberen Abschnitt des Sternum wo eine Gruppe von Lymphknoten stets vorhanden war, hinter welchen sich ein lymphoider Plexus fullte

RÉSUMÉ

Les auteurs ont fait une lymphographie du diaphragme sur 35 chiens Un vaisseau lymphatique diaphragmatique principal a une direction postéro-anterieure, recevant plusieurs branches provenant du diaphragme Il se termine dans un double canal mammaire interne qui se termine à l'extremite supérieure du sternum ou il y a un groupe de ganglions lymphatiques constants au delà desquels se remplit un plexus lymphatique

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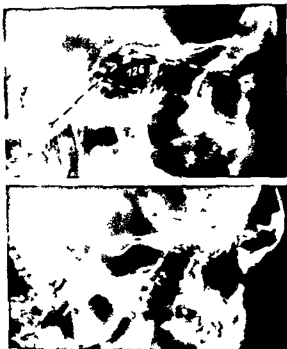


Fig 1 Skull films in 2 cases of Klinefelter s syndrome showing decreased basal angles

with different hormonal disorders (Table) Acromegaly was diagnosed in 41 patients, the diagnosis being based on characteristic manifestations progressive enlargement of the hands and feet, and overgrowth of the face, and on radiography The serum growth hormone concentration was elevated and was not suppressed by glucose loading

Pituitary dwarfism observations based on 60 patients was characterized by a marked stunting of growth, complete lack of sexual maturation, infantile appearance and normal mental development The basal serum growth hormone was low (0 to 4 ng/ml) and did not increase during insulin induced hypoglycemia In 8 patients with primordial dwarfism, apart from significant stunting no other anomalies were found and the serum growth hormone was normal and increased above 10 ng/ml in response to hypoglycemia

In 30 men of ages from 18 to 54 years, eunuchoidism was diagnosed All these patients had eunuchoidal body proportions, excessively long extremities in comparison to the trunk poor muscle development, marked underdevelopment of the genitals, and absence of secondary sex characteristics Chromatin findings were negative, serum luteinizing and follicle stimulating hormones were undetectable or definitely lowered in 23 cases In these patients hypogonadotropic eunuchoidism was diagnosed In 5 other patients with anorchism absence of the testes was found both on examination and at laparotomy, serum and urinary LH and FSH were elevated In the remaining 2 patients eunuchoidism resulted from postinflammatory testicular atrophy

Table

Dimensions of the basal angle on skull films

Syndrome	No of cases	The angle of the base			Incidence of abnormalities (per cent)
		Normal	Increased	Decreased	
Turner's syndrome	53	13	40	0	75
Klinefelter's syndrome	23	7	0	16	70
XYY syndrome	3	0	0	3	100
XXX syndrome (superfemale)	1	0	0	1	—
Acromegaly	41	35	6	0	15
Pituitary dwarfism	60	60	0	0	0
Primordial dwarfism	8	8	0	0	0
Eunuchoidism	30	28	0	2	7
Adrenogenital syndrome	10	10	0	0	0
Male pseudohermaphroditism	7	7	0	0	0
Congenital hypothyroidism	16	14	2	0	14
Microcephaly	53	53	0	0	0
Craniostenosis	36	2	34	0	94
Control subjects aged 3 to 60 years	230	230	0	0	0

manifestations short stature, primary amenorrhea and congenital anomalies of which the most common were in the skeletal system Chromatin findings in buccal smears were negative in 31 cases, and positive in the remaining patients Chromosome determinations were performed in 22 cases and showed a 45,X constitution in 17 cases and mosaicism 45,X/46,XX in 5 cases Vaginal smears were atrophic, indicating definite estrogen deficiency The serum luteinizing hormone (LH) and follicle-stimulating hormone (FSH), as determined by radioimmunoassay, were greatly elevated to the postmenopausal range

The patients with Klinefelter's syndrome, aged 13 to 37 years, presented small firm testes, deficient sexual development of varying degrees, sterility and occasionally gynecomastia Chromatin findings in buccal smears were positive in all patients Karyotyping from peripheral blood showed a 47,XXY constitution The serum follicle-stimulating hormone was increased in all cases and the serum luteinizing hormone in the majority of patients

Three male patients (18, 19 and 37 years old) with an XYY syndrome were of excessive height (194 to 204 cm) and slim build, and had normal sexual development In buccal smears a double fluorescent body was found in microscopy The karyotype showed 47,XYY chromosomes A case of extra X chromosome with 47,XXX constitution was observed in a 28-year-old female patient with mental deficiency, congenital anomalies, myotonic dystrophy and abnormal palm creases

Measurements of the basal angle of the skull were also carried out in patients

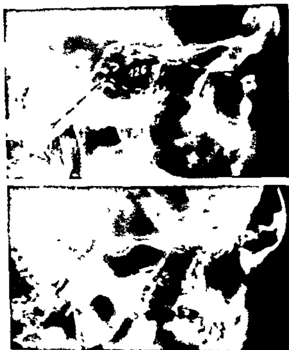


Fig. 1. Skull films in 2 cases of Klinefelter's syndrome showing decreased basal angles

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Eunuchoidism	30	28	0	2	7
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Measurements of the basal angle of the skull were also carried out in patients



Fig 2 Skull films in 2 cases of Turner's syndrome illustrating increased basal angles, typical of the disorder

In 35 cases of acromegaly the basal angle was normal, whereas in 6 cases it was enlarged, which should be attributed to the displacement of the tubercle of the sella

In 8 patients with primordial dwarfism the basal angle was found to be normal On the other hand, among 16 patients with congenital hypothyroidism, in 2 cases the basal angle was increased to 137° and was associated with absence of pneumatization of the sphenoid sinuses and a low position of the sella turcica

The greatly reduced size of the skull in 53 patients with microcephaly did not influence the growth of the base of the skull as the basal angle was normal It was enlarged and ranged from 136 to 159° in 34 of 36 patients with craniostenosis

Discussion

The results indicate a relationship between the development of the base of the skull and sex chromosome aberrations The absence of one sex chromosome, e g the 45,X syndrome, is associated with an enlarged angle of the base, whereas patients with extra sex chromosomes either with an additional X or Y chromosome (or multiple sex chromosomes) are characterized by a decreased basal angle Since sex chromosome *aberrations*, particularly Turner's syndrome and Klinefelter's syndrome, are associated *with* gonadal hormonal deficiency and absent sexual maturation, the question had arisen whether the pathologic alterations of the angle are *the result*

In the group of 10 patients with an adrenogenital syndrome, there were 3 boys and 7 girls. In the female patients the genitals were ambisexual, growth was accelerated and there were signs of virilization. Urinary 17-ketosteroids and 17-ketogenic steroids were grossly elevated and dropped to normal on cortisone administration. Radiography of the skeleton revealed an accelerated bone age, premature fusion of the epiphyses, and premature calcification of the rib cartilages. In 7 patients with male pseudohermaphroditism the genitals were typically ambisexual, chromatin findings were negative and there was a normal male chromosome constitution, 46,XY. Five of these patients belonged to the testicular feminization syndrome. In patients aged 3 to 10 years with congenital hypothyroidism, physical and mental development was delayed. They displayed short stature, pale and dry skin, and in most cases puffiness of the face and dorsal aspects of the hands. Serum triiodothyronine and thyroxine concentrations at radioimmunoassay were lowered whereas the serum thyreotropic hormone was greatly elevated. Radiography revealed a markedly delayed bone age and epiphyseal dysgenesis of the femoral heads.

For comparative purposes the basal angle was measured on skull films in 53 cases of microcephaly and in 36 cases of craniostenosis as well as in 230 healthy subjects (RZYMSKI 1971).

Results

In 40 of the 53 patients with Turner's syndrome the basal angle was increased and measured 136 to 146°, and in 16 of the 23 patients with Klinefelter's syndrome the basal angle was decreased, ranging from 123 to 130°. Similarly, in 3 patients with an excess of Y chromosome, the so-called XYY syndrome, with chromosome constitution 47,XYY and in one female patient with 47,XXX constitution, the basal angle was decreased. Hence, there was a relationship between the number of sex chromosomes and the size of the basal angle. Reduced numbers of sex chromosomes were associated with an increased basal angle, whereas a reduction of this angle appeared in patients with supernumerary sex chromosomes.

Abnormalities of the basal angle of the skull occurred rarely in patients with hormonal disorders. In all 60 cases of pituitary dwarfism a normal basal angle was found. In the group of 30 patients with eunuchoidism 28 cases had a normal basal angle and only 2 had slightly reduced basal angles, 129° in both cases.

In 7 males with pseudohermaphroditism, no change of the angle was found. The angle was also within the normal range in patients with a congenital adrenogenital syndrome. These observations indicate that severe hormonal disturbances such as complete deficiency of growth hormone, deficiency or excess of androgens, or abnormal gonadal development alone (without sex chromosome aberrations) have no influence on the development of the basal angle.

In patients with acromegaly the sella turcica was enlarged because of the expanding intrasellar tumor and in some cases the tubercle of the sella was displaced anteriorly



Fig. 2 Skull films in 2 cases of Turner s syndrome illustrating increased basal angles typical of the disorder

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The results indicate a relationship between the development of the base of the skull and sex chromosome aberrations The absence of one sex chromosome, e g the 45 X syndrome, is associated with an enlarged angle of the base, whereas patients with extra sex chromosomes either with an additional X or Y chromosome (or multiple sex chromosomes) are characterized by a decreased basal angle Since sex chromosome aberrations particularly Turner s syndrome and Klinefelter s syndrome, are associated with gonadal hormonal deficiency and absent sexual maturation, the question had arisen whether the pathologic alterations of the angle are the result

of hormone deficiency or whether they depend on chromosome abnormalities A *deficiency or excess of sex hormones* alone had no influence on the basal angle Hence, there is clear evidence that basal angle abnormalities should be directly attributed to chromosome aberrations, if congenital disturbance of the cranial development such as craniostenosis is excluded

Conclusions

(1) In patients with a deficiency of one sex chromosome, e g in Turner's syndrome with 45,X constitution, the basal angle in the great majority of cases is definitely greater than that met with in normal subjects In developmental disturbances a high frequency of increased basal angle exists only in craniostenosis

(2) Patients with extra sex chromosomes, Klinefelter's syndrome, XYY syndrome or XXX syndrome have a decreased angle of the base

(3) Changes in the size of the basal angle are not the result of accompanying hormonal deficiency since lack of growth hormone in pituitary dwarfism, excess of androgens in adrenogenital syndrome, or complete lack of androgens in anorchism have no influence on this angle

SUMMARY

The basal angle was measured on skull films in 252 patients with hormonal disorders and sex chromosome aberrations In cases of hormonal disturbance the basal angle was normal In patients with Turner's syndrome (45,X chromosomes) the basal angle was enlarged while in patients with Klinefelter's syndrome (47,XXY chromosomes) and in those with extra X or Y chromosomes it was definitely reduced A close relationship exists between the sex chromosome number and the size of the basal angle

ZUSAMMENFASSUNG

Der Schädelbasiswinkel wurde bei 252 Patienten mit Hormonstorungen und Abweichungen der Geschlechtschromosome gemessen In Fällen mit Hormonstorungen war der Winkel normal Bei Patienten mit dem Turnerschen Syndrom (45,X Chromosome) war der *Winkel vergrossert, bei Patienten mit dem Klinefelterschen Syndrom* (47,XXY Chromosome) oder mit extra X oder Y Chromosome war der Winkel jedoch verkleinert Eine enge Korrelation bestand zwischen der Anzahl der Geschlechtschromosome und der Grosse des Schadelbasiswinkels

RÉSUMÉ

L'angle basal a eté mesure sur des radiographies du crâne de 252 malades atteints de troubles hormonaux et d'aberration des chromosomes sexuels Dans les cas de troubles hormonaux l'angle basal était normal Chez les malades atteints de syndrome de Turner (45,X chromosomes) l'angle basal était augmenté alors que chez les malades ayant *un*

syndrome de Klinefelter (47,XXY chromosomes) et chez les malades qui avaient des chromosomes X ou Y supplementaires, l'angle basal était nettement réduit Il existe une etroite relation entre le nombre des chromosomes sexuels et la grandeur de l'angle basal

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, UNIVERSITY HOSPITAL, S-221 85 LUND, SWEDEN.

ANGIOGRAPHY IN CARCINOMA OF THE RENAL PELVIS AND THE URETER

L. EKELUND and J. GÖTHLIN

Only a few comprehensive reports have been published concerning angiography in renal pelvic carcinoma (BOIJSEN & FOLIN 1961, BRUNNER 1972, RABINOWITZ et coll. 1972). Reports on angiography in ureteric carcinoma are also rare (BOIJSEN 1962, SIEGELMAN et coll. 1968, LANG 1969). Both conditions may cause hydronephrosis and angiography may contribute to the differential diagnosis. As these tumours require a nephro-ureterectomy, a correct preoperative diagnosis is essential. In an attempt to assess the value of angiography in these entities, the experiences at this hospital are now reported.

Material and Methods. The material, collected since 1964, comprised 27 patients, 18 males and 9 females, aged between 36 and 76 years, and was divided into three groups: (1) Carcinoma confined to the renal pelvis (17 cases), (2) carcinoma of the renal pelvis and proximal ureter (4 cases) and (3) carcinoma of the ureter (6 cases). All patients belonging to groups 1 and 2 were examined with selective nephroangiography and some also with aortography. In 4 cases pharmacoangiography with 0.5 μg angiotensin, administered intraarterially, was also employed. Lumbar aortography and selective nephroangiography were performed in group 3, in addition angiography of the iliac artery was performed in 3 and selective angiography of one lumbar artery in one of these patients.

Urography was performed in all cases and retrograde pyelography or ureterography in 16 cases. The diagnosis was confirmed microscopically at operation or at autopsy in all cases.

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Table 1

Result of angiography in 21 patients with carcinoma of the renal pelvis and proximal ureter (groups 1 and 2)

Findings	Number of patients	
	Pos	Neg
Pelviureteric artery widened	11	10
Neovascularity	15	6
Visible capillary phase	16	5
Vessel encasement	8	13
Hydronephrosis	13	8
Arteriovenous shunting	0	21

Table 2

Result of angiography in 6 patients with ureteric carcinoma (group 3)

Findings	Number of patients	
	Pos	Neg
Pelviureteric artery widened	2*	4
Neovascularity	4	2
Visible capillary phase	5	1
Vessel encasement	2	4
Arteriovenous shunting	2	4

* Carcinoma located in proximal and middle part of ureter, respectively

Results

The result of the angiography in groups 1 and 2 appears in Table 1 Thirteen patients were referred because of macroscopic haematuria Hydronephrosis existed in 13 and a non-functioning kidney at urography in 7 cases

No abnormality was detected at angiography in 3 patients with renal pelvic carcinoma measuring 10 mm × 5 mm, 10 mm × 7 mm and 10 mm × 8 mm, respectively These tumours were all demonstrated at urography and pyelography In another small tumour of the renal pelvis, measuring 8 mm × 15 mm, a faint accumulation of contrast medium occurred at conventional angiography, somewhat enhanced after 0 5 μg angiotensin Selective angiography of the contralateral kidney in this patient revealed a tumour on this side as well

Angiography in a 61-year-old man with a highly differentiated papillary carcinoma of the renal pelvis, measuring 3 5 cm × 2 cm, demonstrated a large hydronephrosis but no evidence of malignancy

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L EKELUND and J GÖTHLIN

Only a few comprehensive reports have been published concerning angiography in renal pelvic carcinoma (BOIJSEN & FOLIN 1961, BRUNNER 1972, RABINOWITZ et coll 1972) Reports on angiography in ureteric carcinoma are also rare (BOIJSEN 1962, SIEGELMAN et coll 1968, LANG 1969) Both conditions may cause hydronephrosis and angiography may contribute to the differential diagnosis As these tumours require a nephro-ureterectomy, a correct preoperative diagnosis is essential In an attempt to assess the value of angiography in these entities, the experiences at this hospital are now reported

Material and Methods The material, collected since 1964, comprised 27 patients 18 males and 9 females, aged between 36 and 76 years, and was divided into three groups (1) Carcinoma confined to the renal pelvis (17 cases), (2) carcinoma of the renal pelvis and proximal ureter (4 cases) and (3) carcinoma of the ureter (6 cases) All patients belonging to groups 1 and 2 were examined with selective nephroangiography and some also with aortography In 4 cases pharmacoangiography with 0 5 μg angiotensin, administered intraarterially, was also employed Lumbar aortography and selective nephroangiography were performed in group 3, in addition angiography of the iliac artery was performed in 3 and selective angiography of one lumbar artery in one of these patients

Urography was performed in all cases and retrograde pyelography or ureterography in 16 cases The diagnosis was confirmed microscopically at operation or at autopsy in all cases

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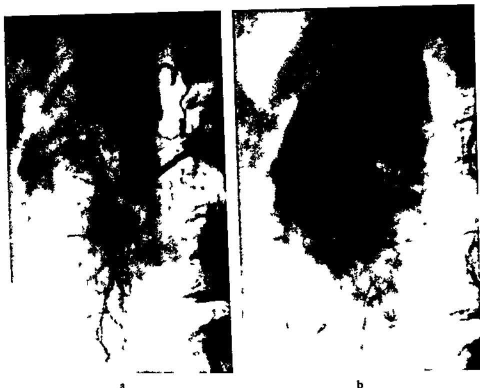


Fig 3 a) Extensive arterial encasement of main renal artery with descending branches. b) Tumour vascularity demonstrated to better advantage after 0 5 μg angiotensin

at urography, while the remaining 2 patients had a wide ureter down to the tumour Four of the tumours were located in the distal part of the ureter, one in the middle and one in the proximal part of the ureter

Abundant neoplastic vessels occurred in 2 patients with carcinoma of the distal part of the ureter At urography, a non functioning right kidney was demonstrated in a 60-year old female with haematuria Bilateral selective nephroangiography revealed a large hydronephrosis on the right side and no abnormality on the left At selective angiography of the right internal iliac artery, a 3 5 cm × 3 cm, richly vas cularized tumour with vascular encasement, arteriovenous shunting and accumulation of contrast medium was found in the distal part of the ureter, close to the bladder (Fig 6) Nephro-ureterectomy and local bladder resection were performed The microscopic diagnosis was infiltrating papillary ureteric carcinoma

A 64-year old woman had two years previously been operated upon with nephrectomy and ureteral resection because of a carcinoma located in the middle part of the ureter A repeat angiography of the right internal iliac artery because of haematuria revealed a tumour in and around the distal part of the ureter with vascular encasement abundant neovascularity and early arteriovenous shunting



Fig 1



Fig 2

Fig 1 Large carcinoma with arterial encasement neovascularity and wide pelvic arteries Atrophy of the parenchyma most evident in lower part of the kidney

Fig 2 Encasement of main renal artery Wide pelviureteric arteries giving off tortuous irregular branches Tumour vessels around main renal artery At operation tumour was found around the hilar vessels

Encasement and occlusion of an artery to the superior pole of the kidney was the only abnormality in a 62-year-old man with carcinoma of the upper calyceal system Arterial encasement combined with neovascularity and visible capillary phase was found in 7 patients with carcinoma confined to the renal pelvis (Figs 1, 2, 3) One of these patients is of particular interest as she was examined twice, the second time due to the appearance of a recurrence after the first operation (Fig 4) The main renal vein was occluded in 2 of these patients The diagnostic information was increased by pharmacoangiography with 0 5 μg angiotensin in 3 patients

Small, newly formed vessels and a faint accumulation of contrast medium within the tumour, but no vascular encasement, were found in 4 patients with tumours fed from a wide pelviureteric artery In altogether 11 patients with carcinoma of the renal pelvis and proximal ureter, the pelviureteric artery was wide This occurred in all 4 patients with tumour involving also the proximal ureter These tumours had a fine network of tortuous and irregular vessels and a visible capillary phase (Fig 5)

Arteriovenous shunting within the tumour was not found in any of the 21 cases in groups 1 and 2

The essential angiographic appearances of the cases with the tumour confined to the ureter (group 3) are given in Table 2 Five cases had haematuria, the sixth lower abdominal pain A non-functioning kidney was demonstrated in 4 of these patients


Fig. 5


Fig 6a


Fig 6b

Fig. 5 A fine network of tortuous and irregular vessels supplies the tumour in the renal pelvis and proximal ureter

Fig. 6 Selective angiography of right internal iliac artery a) Arterial and b) early venous phase Arterial encasement, abundant neovascularity and arteriovenous shunting within large carcinoma growing into and around distal part of the ureter

mour in the proximal part of the ureter was fed from an 1 3 mm wide pelviureteric artery A fairly marked accumulation of contrast medium within the tumour was evident This patient also had a carcinoma in the right side of the bladder

Finally, in a 73-year old man with macroscopic haematuria and a non functioning left kidney, lumbar aortography and selective angiography of the left third lumbar artery failed to demonstrate a poorly differentiated carcinoma in the lower half of the ureter

Discussion

Before 1961 it was generally assumed that carcinoma of the renal pelvis was avascular at angiography in the majority of cases However, BOIJSEN & FOLIN (1961) reported on a material of 10 cases with renal pelvic carcinoma in which small tumour vessels were found in 7 These authors also stressed the diagnostic significance of a wide pelviureteric artery, which almost never occurs in hydronephrosis not caused by a tumour This fact was further emphasized by RABINOWITZ et coll (1972) who found a wide pelviureteric artery in 12 out of 22 cases of renal pelvic carcinoma In 18 of these neovascularity and an accumulation of contrast medium within the tumour were evident Widening of the pelviureteric artery in renal pelvic carcinoma has also

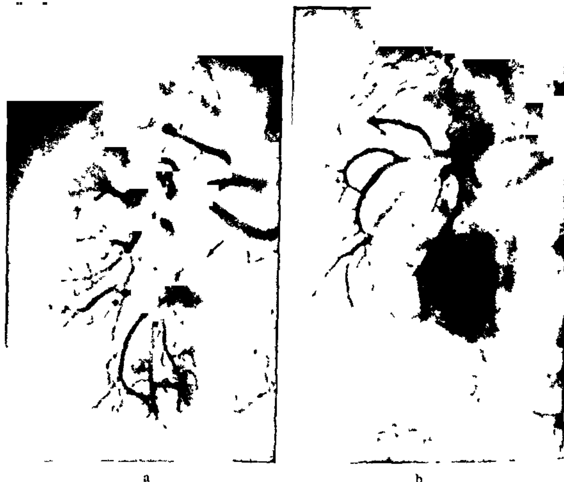


Fig 4 a) Delicate neovascularity (→) in a pelvic tumour which was resected b) 15 months later recurrence with abundant neovascularity Metastasis in the adrenal gland

Urography in a 69-year-old man with macroscopic haematuria revealed dilatation of the right renal pelvis and ureter down to a stricture in the distal part of the ureter At retrograde ureterography the stricture was found to be 3 cm long with irregular margins Angiography of the right internal iliac artery revealed tiny newly formed vessels and an accumulation of contrast medium corresponding to the stricture The diagnosis of ureteric carcinoma was confirmed at surgery and nephroureterectomy performed

At urography of a 46-year-old man with right-sided lower abdominal pain, a non-functioning right kidney was found Selective angiography demonstrated a large hydronephrosis The pelviureteric artery was wide and displaced medially Branches from this artery fed an ureteric tumour with faint accumulation of contrast medium A solid, poorly differentiated ureteral carcinoma was found at surgery

A non-functioning right kidney was also demonstrated in a 76-year-old woman examined because of massive haematuria A large hydronephrosis was found at selective angiography An approximately 7 cm long, moderately vascularized tu-

Renal vein thrombosis may develop in carcinoma of the renal pelvis (RENERT et coll 1972) and occurred in 2 of the present cases

Three of the renal pelvic carcinomas had a diameter of 10 mm only, angiography in these cases did not demonstrate any abnormality In another case with a tumour diameter of 15 mm, a faint accumulation of contrast medium in the capillary phase was the only abnormality at angiography In these cases the tumours had been documented by previous urography and retrograde pyelography Apparently angiography is of no or doubtful value in small tumours of the renal pelvis (diameter less than 1 5 cm) The advantages of angiography should primarily be taken into consideration in cases with obstruction of the urinary flow The diagnostic information may sometimes be increased by pharmacoangiography with angiotensin This was the case in 3 of the present patients

Angiography may also be of value for the distinction between carcinoma of the ureter and obstruction or narrowing by other disease (LANG 1969) Ureterography will not always distinguish the various entities which may produce a non-functioning hydronephrotic kidney BOIJSEN (1962) reported on 2 cases of ureteric carcinoma where angiography revealed small tumour vessels in both Referring to the sources of blood supply to the various parts of the ureter, he also stated that if the upper ureter is involved the examination should be performed as selective nephroangiography, and when the tumour is located in the middle parts, as lumbar aortography If the lower part of the ureter is involved, angiography of the common iliac artery should be carried out

A network of tumour vessels was observed in 3 cases of carcinoma of the proximal ureter (SIEGELMAN et coll 1968) The neoplasms were supplied by branches from the aorta, the renal artery and a wide ureteric artery, respectively

Arterial encasement and early arteriovenous shunting, not being observed in the cases described by BOIJSEN and SIEGELMAN et coll , were observed in 2 of the present cases with carcinoma of the lower ureter, as well as abundant neoplastic vessels A wide ureteric artery was supplying the tumour in 2 of the cases with carcinoma located in the proximal and middle part of the ureter, respectively

Angiography may thus be of value for the differential diagnosis of obstruction of the ureter and also sometimes provide valuable information about the extent of tumour growth However, this by no means indicates that angiography should be routinely performed in the examination of patients with ureteric obstruction

SUMMARY

Angiographic findings in 21 cases of renal pelvic carcinoma are presented Important characteristics include neovascularity, visible capillary phase, vascular encasement wide pelviureteric artery and absence of arteriovenous shunting Angiography may also be of value for the differential diagnosis of ureteric obstruction as demonstrated in 5 of 6 patients with carcinoma of the ureter



Fig 7 Tumour in renal pelvis and proximal part of ureter (→) Advanced arteriolosclerosis, easily confused with arterial encasement, which, however, often is more localized

been reported as a characteristic angiographic finding by SCHAPIRA & MITTY (1971), BRÜNNER (1972) and CUMMINGS et coll (1975) Neither BOIJSEN & FOLIN nor RABINOWITZ et coll found any evidence of arteriovenous shunting within the tumour The present findings are in good agreement with their experiences Tumour vessels, more or less delicate, were observed in 15 of the present cases, and an accumulation of contrast medium within the tumour in 16 of 21 patients with renal pelvic carcinoma A wide pelviureteric artery was observed in 11 cases, the diameter ranging from 1 0 to 1 9 mm Abnormal arteriovenous shunting was not evident in any case

MITTY et coll (1969) reported on the angiographic features in 4 cases of infiltrating carcinoma of the renal pelvis The vascular abnormalities described were limited to encasement and occlusion Vascular encasement was also considered as an important diagnostic sign by RABINOWITZ et coll and was encountered in 16 of their 22 cases Unequivocal encasement was found in 8 of the present cases However, it should be emphasized that encasement should not be confused with generalized arteriolosclerosis (Fig 7) BECKER & KANTER (1968) described 2 cases of arterial encasement in transitional cell carcinoma, where microscopy demonstrated that tumour tissue was encircling the vessel, but not invading its wall Vascular encasement without neovascularity may also be encountered in metastases to the kidney (BOSNIAK et coll 1969, LEMAÎTRE et coll 1975)

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RENAL ARTERY LESIONS AFTER *PYELOLITHOTOMY*

A potential cause of renovascular hypertension

INGVAR ANDERSSON

Pyelolithotomy is usually performed through an incision in the posterior wall of the renal pelvis Although most of the renal vessels run in front of the pelvis, important vessels pass also on its posterior aspect Thus, in more than 50 per cent of cases the dorsal renal artery arises as the first branch from the main stem, running an almost horizontal course to the upper posterior aspect of the renal pelvis where it turns caudally in a more or less vertical course often parallel to the posterior hilar lip (BOIJSEN 1959) Occasionally the dorsal artery divides early into several branches running at different levels behind the pelvis (EISENDRATH 1920)

If the dorsal artery is a supplementary artery, i e. arises from the aorta, it may run together with the main artery or may have a separate course to the kidney

The supplementary arteries to the lower pole, usually supplying both dorsal and ventral pyramids, have a varying course, mainly depending on their level of origin from the aorta (BOIJSEN)

Beside the dorsal artery, a branch of the renal vein or in exceptional cases even its main stem may pass along the dorsal aspect of the kidney pelvis (EISENDRATH)

Pyelolithotomy involves a certain risk of injuring the dorsal renal vessels

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ZUSAMMENFASSUNG

Die angiographischen Befunde von 21 Fällen mit einem Karzinom des Nierenbeckens werden vorgelegt Wesentliche Charakteristika umfassen die Neovaskularität, die sichtbare kapilläre Phase, die Gefässverengung, eine weite pelvi-uretäre Arterie und das Fehlen von arteriovenösen Shunts Die Angiographie kann auch bei der Differentialdiagnose von Obstruktionen der Ureteren von Wert sein, wie bei 5 von 6 Patienten mit einem Karzinom des Ureters demonstriert wurde

RÉSUMÉ

Présentation des signes angiographiques dans 21 cas de cancer du bassinet rénal Les caractéristiques importantes comprennent une néovascularisation, une phase capillaire visible, un corbeillage vasculaire, une artère pyélo-urétérale large et l'absence de shunt artério-veineux L'angiographie peut aussi avoir de l intérêt pour le diagnostic différentiel avec l'obstruction urétérale, comme le montrent 5 des 6 malades atteints de cancer de l uretère

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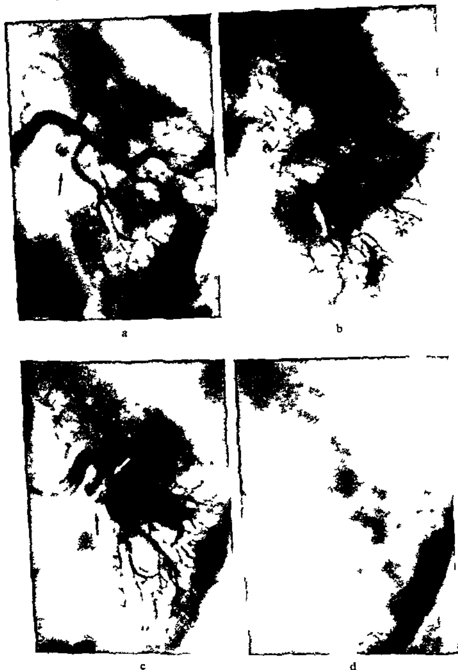


Fig 1 Case 1 Occlus on of the dorsal artery a) b) A p and c) d) oblique projection
h f f he k dney Thro gh scanty

Case reports

Case 1. A 45-year-old man with a large intake of phenacetin because of back pain Pyelolithotomy was performed because of a calculus in the left kidney pelvis causing obstruction to the urinary flow The kidney was surrounded by dense fibrous tissue and during dissection of the ureteropelvic region a small artery was injured and ligated Signs of ischemia were observed in an area measuring about 2 cm 4 cm The stone was removed and the postoperative course was uneventful

Urography was performed 3 and 7 weeks after the operation The left kidney pelvis was slightly dilated but the renal function was normal Papillary necroses were present in the upper and lower poles The right kidney was normal except for two small papillary calcific deposits

A few weeks after operation the patient began to complain of headache and dizziness Previous to operation he was normotensive but 3 months postoperatively hypertension was diagnosed with blood pressure around 190/120 mmHg Heavy proteinuria was found but otherwise the urine was normal Renin analysis was not performed Urography 3 months after operation revealed a reduction of the volume of the upper pole of the left kidney Two small calculi were found in the pelvis and a few small calcific deposits in the papillae of the lower pole of the kidney

At nephroangiography the left dorsal artery was found to be occluded at its origin (Fig 1) In the renal sinus small collaterals from the branches of the ventral artery could be demonstrated Through these collaterals a faint filling of the branches of the dorsal artery in the upper and middle parts of the kidney occurred late in the arterial phase The volume of the kidney was reduced in these areas

The hypertension was thought to be due to the reduced blood flow in the area supplied by the dorsal artery It could be controlled by administration of antihypertensive drugs and reconstructive surgery was not considered possible

Case 2 A 38-year-old man who 17 years before admission had a right renal calculus removed He had now bilateral calculi, one at the left ureteropelvic junction causing considerable obstruction A left pyelolithotomy was performed Abundant perinephritic fibrous tissue made the operation difficult Heavy bleeding occurred from an artery located close to the kidney The artery was ligated and the stone removed without further complications

The dilatation of the left renal pelvis decreased during the following 20 months The left kidney which was larger than normal preoperatively slowly returned to normal size The parenchyma was, however, reduced in the whole kidney The right kidney which increased in size during this period was normal except for two calculi in the caudal calices

The blood pressure was around 150/100 both pre- and postoperatively

Removal of the stones in the right kidney pelvis was considered As the operation might require removal of the kidney with subsequent autotransplantation a nephroangiography was performed 20 months postoperatively to delineate the vascular anatomy This examination revealed an occlusion of the left dorsal artery, which was filled through collaterals from the ventral artery (Fig 2) The parenchyma was reduced in the whole kidney but above all in the part supplied by the dorsal artery The right kidney was normal except for compensatory hypertrophy

Case 3 A 30-year-old woman with a left femoral fracture and a cerebral contusion after a traffic accident The course was complicated by urinary infection and the formation of a large calculus in the left renal pelvis Operation was postponed because of pregnancy One and a half years after the accident a pyelolithotomy was performed The left kidney was



Fig 3 Case 3 a) Arterial phase Only ventral branches and arterial collaterals filled The main stem of the dorsal artery is occluded b) The branches of the dorsal artery are fed by pelvic collaterals

to the surface of the kidney indicating a considerable reduction of the parenchyma in this area

Another pyelotomy was performed The ureter and kidney pelvis were found to be surrounded by fibrous tissue but the stone could be removed without complication Postoperatively urinary leakage occurred from the upper part of the ureter which ceased within a few weeks

Nephroangography was performed 4 months postoperatively because of high sedimentation rate possibly due to tumor However no tumor was demonstrated The parenchyma of the left lower pole was markedly reduced and no arteries passed to the lower pole of the kidney nor were there any collaterals (Fig 4) It could not be determined whether the lower pole had previously been supplied by a supplementary artery or a branch from the main artery The arterial supply of the remaining part of the kidney was normal as were the arteries of the right kidney which was supplied by a main artery and a separate artery to the lower pole

The blood pressure was normal

Case 5 A 62 year old woman with a long history of urinary infection Repeated urographies in the years preceding admission demonstrated gradual enlargement of calculi in both renal pelves

A right pyelotomy was performed The operation was complicated by the presence of



Fig 2 Case 2 Late arterial phase The dorsal artery is occluded and is supplied by collaterals from the ventral artery at different levels in the sinus (→) Part of the upper pole is supplied by a supplementary artery

surrounded by dense fibrous tissue making dissection difficult Heavy bleeding occurred from a vessel which could not be identified and which had to be ligated The kidney pelvis was opened and the stone removed

Postoperatively the urinary infection persisted At urography 5 months after operation several calculi were observed in the left pelvis and evidence of pyelonephritis in the upper part of the kidney The right kidney was normal

At nephroangiography one month later the main branch of the left dorsal artery was found to be occluded The branches of the dorsal artery were fed by collaterals from the ventral artery (Fig 3) The parenchyma was considerably reduced particularly in the cranial part of the kidney

Nephrectomy was performed as reconstructive surgery was not considered possible

The blood pressure was normal or slightly elevated (max 130/100) throughout the course

Case 4 A 69 year old man with a history of surgically treated left renal pelvic calculus 10 years previously According to the operation report a rather large artery and vein were seen to emerge from the psoas muscle running close to the renal pelvis just over the area where the stone was located The artery was too large to be ligated and the renal pelvis was opened above the vessels The stone was removed without complication The postoperative course was uneventful

The patient was now admitted for evaluation of left flank pain Urography revealed a calculus measuring 10 mm × 5 mm in the most cranial part of the left ureter The excretion was greatly delayed Another small calculus was located in one of the caudal calices close

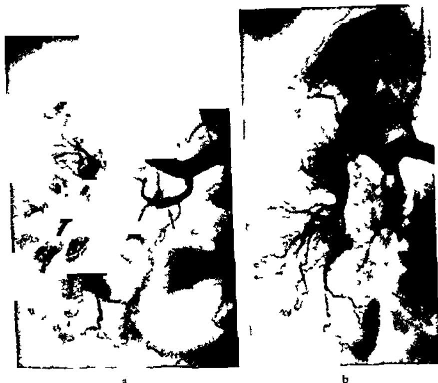


Fig 5 Case 5 Arterial phase a) A p and b) oblique projection The dorsal artery is reduced in calibre Three small aneurysms on its main stem (→) peripheral branches small and reduced in number

well as ischemia in part of the kidney were observed during operation In case 1 the artery was obviously ligated In case 5 an injury to the dorsal branch of the renal artery occurred during operation repaired by suturing However a normal circulation could not be restored to the part of the kidney supplied by the dorsal renal artery The injured part of the vessel wall with its aneurysms could possibly be the source of emboli obliterating parts of the peripheral vascular bed thus explaining the reduction of kidney volume and circulation The changes could also represent a post thrombotic state with recanalization

In cases 2 and 3 the operation was complicated by heavy bleeding which may well have originated from the dorsal renal artery the occlusion demonstrated postoperatively on angiography thus being the result of an emergency ligation In these 4 patients perirenal adhesions made the operation difficult

In case 4 the occlusion of the artery to the lower pole of the kidney must be considered as a sequela of the first operation Such a view is supported by the fact that before the second operation a local reduction in kidney volume comprising the inferior pole of the kidney could be demonstrated at urography



Fig 4 Case 4 Selective nephroangiography Considerable reduction of the lower pole probably as the result of infarction on the basis of arterial occlusion The lower pole of the opposite kidney was supplied by a supplementary artery but no further arteries were found to supply the left lower pole

perinephritic adhesions During dissection of the dorsal aspect of the kidney pelvis the dorsal renal artery was injured An ischemic area was observed on the dorsal surface of the kidney surrounding the hilum The artery was clamped for a few minutes while the laceration was sutured The circulation improved but was not completely restored to normal The kidney pelvis was found to be filled with an amorphous calculous mass which was difficult to remove completely

Postoperatively the urinary infection persisted Repeated urographies during the following months showed that stones were still present in the right pelvis The volume of the right kidney was reduced especially in the middle part as compared with the preoperative films The excretion was normal as was the blood pressure

Nephroangiography was performed 9 months postoperatively The right dorsal artery and its branches were reduced in calibre (Fig 5) About 1 5 cm distal to its origin from the main renal artery 3 small aneurysms were observed The circulation was slow in the dorsal artery as compared with the ventral artery The parenchyma was reduced in the area supplied by the dorsal artery in the middle and inferior parts of the kidney The branches of the ventral artery were normal except for small changes in calibre

Two years later a right nephrectomy was performed Microscopy revealed chronic pyelonephritis The patient was normotensive

Discussion

The connection between the operation and the arterial injury demonstrated on angiography seems evident in cases 1 and 5 In these patients an arterial lesion as

the possibility of coexisting hypertension being etiologically related to this lesion and not to a vascular occlusion following a pyelolithotomy must be considered Case 1 may have a phenacetin lesion. However, this patient was normotensive before the operation and the hypertension developed after the pyelolithotomy A relationship between the hypertension and the occlusive arterial lesion therefore seems most likely

In case 3 a slightly elevated blood pressure was noticed on a few occasions This patient was normotensive preoperatively Microscopy of the extirpated kidney revealed advanced pyelonephritis Case 2 was slightly hypertensive both pre- and postoperatively The remaining two patients were normotensive

Nephroangiography is the decisive examination in these cases Good technical quality and thorough knowledge of the anatomy of the renal vessels are essential as the abnormalities are not always conspicuous Practically always the dorsal renal artery can be identified in an a p projection by its characteristic course in the sinus where it crosses the branches of the ventral artery (BOIJSEN 1959) More peripherally crossing arteries are seen in the whole kidney The branches of the dorsal artery do not cross one another in areas where the dorsal artery supplies dorsal pyramids only In the same way the branches of the ventral artery do not cross each other in areas where the ventral artery supplies ventral pyramids only A consistent division of the arterial supply is observed only in the intermediate part of the kidney where the dorsal artery supplies the dorsal pyramids and the ventral artery the ventral pyramids The blood supply of the remaining parts of the kidney is variable with the exception of the ventral pyramids of the pars inferior, these pyramids almost always being supplied by the ventral artery Thus, it is important to observe the absence of crossing arteries in part of the kidney (Figs 1 a, 3 a) which may be the only indication of a branch occlusion when no collateral circulation is visible

The parenchymatous phase may be delayed or weak in the area supplied by the occluded artery Usually the volume of the part of the kidney involved is reduced due to ischemic atrophy or infarction The defect in the parenchymatous phase as well as the locally reduced volume are most readily registered in a lateral projection of the kidney if only dorsal segments are engaged (Fig 1 c, d)

In cases of segmental artery occlusion the principal collateral circulation may be established through small nutrient vessels in the pelvic area and at the level of the calices (Figs 1 2, 3) The demonstration of collateral circulation is important in the evaluation of the hemodynamic significance of stenosis or occlusion (BOOKSTEIN 1968) Selective catheterization of the renal artery is essential to demonstrate this type of reno-renal collateral circulation and is absolutely necessary to demonstrate scanty collaterals If the collateral circulation is sufficient the peripheral branches of the occluded artery will be filled late in the arterial phase (Figs 2, 3 b)

The value of urography for revealing ischemic lesion involving only part of the kidney is limited Furthermore, the signs of renal artery stenosis or occlusion in the form of delayed appearance of the contrast medium and late hyperconcentration (BOOKSTEIN et coll 1972) are of less importance in these cases, as differences in ap-

The surgical importance of the dorsal renal vessels, mainly as a cause of postoperative hemorrhage following pyelolithotomy, was first pointed out by EISENDRATH (1920) and HELLSTRÖM (1928) Beside the loss of parenchyma the most important consequence of an occluding lesion of the renal artery or one of its branches is the potential risk of hypertension on the basis of renal ischemia As early as 1936 BERGENDAHL observed that ligation of a lower polar artery in the treatment of certain types of hydronephrosis was sometimes followed by hypertension Later several reports have confirmed this observation Many authors report that hypertension in such cases develops only in a few per cent, while BOEMINGHAUS & GÖTZEN (1952) in a series consisting of 36 patients noted postoperative hypertension in 7 cases, i e in about 19 per cent

Renovascular hypertension has been reported after various operative procedures in the renal region, particularly after surgery for pheochromocytoma (CASTLE 1973, JULIAN et coll 1974, YOUNG et coll 1969, FONTAINE et coll 1965) Hypertension after operation for renal pelvic calculus with lesions of polar arteries was reported by GRABSTALD (1951) and GÖTZEN (1956) Iatrogenous renovascular hypertension has also been reported as a complication of selective nephroangiography with a lesion of the intima leading to renal artery occlusion (BERGENTZ et coll 1973, GILL et coll 1972)

The cause of hypertension in such cases may be (1) unintended ligation of a renal artery or thrombosis following mechanical injury to the vessel or (2) hematoma or changes secondary to hematoma compressing the kidney (PAGE 1939, MARSHALL & CASTELLINO 1971)

Traditionally the segmental arteries of the kidney are considered end arteries, at least from a functional point of view However, the occlusion of a segmental artery does not necessarily imply an infarction of the corresponding parenchyma Between the renal arteries in the sinus and also between the interlobar arteries anastomoses exist, which are made up of nutritional branches to the pelvic tissues and the renal parenchyma (HAMMERSEN & STAUBESAND 1961 a, b) Normally only part of these vessels are possible to observe at angiography due to their small calibre However, if they acquire collateral function, they appear as tortuous vessels in the sinus and at the level of the calices BROLIN (1967) was the first to observe these reno-renal collaterals in a case of segmental artery occlusion Recently this type of collateral circulation has been described in cases of stenosis or occlusion of one of multiple renal arteries (ROSENBUSCH et coll 1974)

In cases of branch stenosis the collateral circulation may also be established through capsular, ureteral, lumbar and suprarenal arteries (BOOKSTEIN 1968)

Thus, a certain circulation may be maintained, preventing infarction If, on the other hand, infarction results, there will often be a zone of ischemia in the borderline towards normally supplied parenchyma (CONNOR et coll 1957) In either case the renin-angiotensin system may be activated

Since patients with renal calculi often have an associated parenchymatous lesion,

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SUMMARY

Five cases of renal arterial lesions occurring in conjunction with pyelolithotomy and demonstrated postoperatively at nephroangiography are presented This complication should be kept in mind especially if hypertension develops postoperatively The roentgenologic diagnosis is discussed

ZUSAMMENFASSUNG

Funf Falle mit Verletzungen der Nierenarterien die im Zusammenhang mit einer Pyelolithotomie auftraten und postoperativ durch Nephroangiographie nachgewiesen wurden werden beschrieben Diese Komplikation sollte im Auge gehalten werden besonders wenn postoperativ eine Hypertension auftritt Die rontgenologische Diagnose wird diskutiert

RÉSUMÉ

Présentation de cinq cas de lésions artérielles rénales apparues à la suite d une pyélolithotomie et mises en évidence par néphroangiographie après l opération On doit penser à cette complication en particulier quand une hypertension se développe après l opération L'auteur discute le diagnostic radiologique

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Table

Blood flow determinations proximally and distally in the right and left renal veins and the ratio between the flow determined proximally in the left and right renal vein

Case No	RBF right		RBF left		RBF left/RBF right in per cent
	Dist	Prox	Dist	Prox	prox/prox
1	—	215	470	1 030	470
2	—	1 065	—	2 910	275
3	—	490	750	1 040	210
4	—	95	—	170	180
5	450	720	440	1 090	150
6	—	215	—	315	145
7	—	625	—	820	130
8	—	955	—	1 180	125
9	—	360	—	440	120
10	—	275	—	315	115
11	—	—	440	655	—
12	—	—	375	610	—
M		500		840	190

potentiometer writer Calibration of the system was made after completion of the examination The integration of the curves was made by copying them on stiff carbon paper, cutting them out and comparing the weight with the weight of 100 standard units of the paper The calculation of the blood flow was made according to a modified Stewart Hamilton formula

A 60 cm red catheter (ID/OD 1 4/2 2 mm) with an end-hole was used for arterial catheterization via the femoral artery The tip was placed in the renal artery before its branching For venous catheterization via the femoral vein, the same type of catheter was used except that it had four side-holes close to the tip Initially the tip was placed proximally in the renal vein and in five patients later on distally in the left vein and in one case in the right one Angiography of the renal, coeliac and superior mesenteric arteries was performed in all patients

Results

A summary of the results is presented in the Table The mean value for the blood flow (RBF) in right renal vein was 500 ml/min In 4 of the kidneys the RBF was higher than 600 ml/min In patient No 5 a difference in flow of 270 ml/min occurred when the catheter tip was moved from the proximal to the distal part of the renal vein

The mean value of RBF in the left renal vein was 840 ml/min In eight veins the RBF was higher than 600 ml/min In five veins the flow decreased by 215 ml

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, UNIVERSITY HOSPITAL, S 221 85 LUND, SWEDEN

SPONTANEOUS PORTORENAL SHUNTING IN PORTAL HYPERTENSION ASSESSED BY A DYE DILUTION TECHNIQUE

JAN GÖTHLIN

Because valves are absent in the veins of the portal system, reversed direction of the blood flow frequently occurs in portal hypertension Attention has mainly been drawn to the collateral pathways over the esophageal veins as bleeding from these sites often is lethal Shunting to the renal veins is also known to occur but methods to establish the frequency of smaller shunts have hitherto been lacking The estimation of the blood flow in the renal veins by a dye dilution technique may give the frequency and magnitude of such shunts Therefore, this technique was used and the results are now reported

Material and Methods

In connection with routine angiography in 12 patients with portal hypertension bilateral assessment of the renal blood flow was performed using the dye dilution technique described by GÖTHLIN & OLIN (1973) A bolus of 0 3 ml of indocyanine green (Cardiogreen, Hynson, Westcott & Dunning, USA) was injected into the renal artery while blood was continuously sucked from the renal vein The venous blood passed a spectrophotometer, the deflections of which were recorded on a straight

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to 650 ml/min when the catheter tip was moved from the proximal to the distal part of the renal vein The ratio between the RBF in the left and the right vein (10 patients) was 115 to 470 per cent (mean value 190) In one kidney the right renal artery was stenosed and in another double arteries existed on the right side, which made accurate determinations of RBF impossible (GÖTHLIN & OLIN 1973)

Discussion

Shunts between the portal system and the left renal vein in animals after inducement of portal hypertension has been investigated extensively Thus, in rats BONO et coll (1960) found such communication in nearly 50 per cent and HALVORSEN & MYKING (1974) in 100 per cent A high frequency was also reported in dogs (VITUMS 1959) (For a review of other animals, see VITUMS)

In man portal systemic shunts via the left renal vein have been found at autopsy (EDWARDS 1951, HAINTZ & ROMHÁNYI 1938, LEJARS 1888, MARIAN 1900, THAMM 1940) At splenoportal phlebography reversed circulation in veins of the portal system was found in 97 per cent of patients with portal hypertension, in 28 per cent of these blood flow to the left renal vein could be demonstrated (ROUSSELOT et coll 1959) Collaterals from the splenic and gastric veins to the left renal vein (GILLOT & HUREAU 1960) and communications between the coronary vein and the left renal vein via the left suprarenal vein have been reported (SCHNEIDER & BLUMENSTEIN 1972)

Spontaneous shunts between the portal system and the left renal vein have been demonstrated at percutaneous transhepatic portography in 16 out of 28 patients with portal hypertension (LUNDERQUIST et coll) Shunts between varicose bowel veins and the right ovarian vein have been observed in two patients at angiography (GRAY & GROLLMAN 1974)

In the present material an increased flow was recorded in all renal veins on the left side compared with the right one Normally with the technique used the RBF in the right kidney is mean 460 and in the left kidney 430 ml/min (GÖTHLIN & OLIN) This means that in all patients there is a contribution of blood from other sources than the kidney especially as the renal blood flow is reported to be decreased in liver cirrhosis (BALDUS et coll 1964, KEW et coll 1971, LANCESTREMERE et coll 1962)

The contribution of blood from other sources is also indicated by the difference in blood flow when sampling was made both distally and proximally in the vein a difference of 215 to 650 ml/min was found on the left side and 270 ml/min in one case on the right side Furthermore, on the right side the mean flow was 500 ml/min which is not much more than normal but in 4 patients the flow was higher than the upper limit in all patients (525 ml/min, GÖTHLIN & OLIN) On the left side the mean value was much above normal and in 8 patients above the limits for normal kidneys This means a strong indication of portal systemic shunting in some of the right renal veins and in all of the left ones

Using a dye dilution technique it is only possible to establish that blood is con

tributed to the renal vein from other sources than the kidney but not from where. It may pass to the right renal vein via the right ovarian vein So may be the case on the left side but on this side the path via the left suprarenal vein (LUNDERQUIST et coll) probably is more common

In this material, spontaneous shunting of portal blood to the left renal vein was demonstrated in all cases It is easier to detect addition of blood using the dye dilution technique than by using angiography, portography or splenoportal phlebography The incidence of shunting in portal hypertension is probably 100 per cent

SUMMARY

Using a dye dilution technique, blood flow was measured in the right and left renal veins in 12 patients with portal hypertension There was evidence of spontaneous shunts to the left renal vein in all cases and at least in 4 cases to the right one Spontaneous portal systemic shunts other than via esophageal varices is probably much higher than hitherto known

ZUSAMMENFASSUNG

Mit einer Farbstoffverdunnungs-Technik wurde die Durchblutung in den rechten und linken Nierenvenen bei 12 Patienten mit portaler H
taner Shunts zu
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Ösophagusvari

RÉSUMÉ

En utilisant une technique de dilution de colorant, l'auteur a mesuré le debit sanguin dans les veines renales droite et gauche chez 12 malades atteints d'hypertension portale Il y avait des signes de shunt spontané vers la veine rénale gauche dans tous les cas et vers la veine renale droite dans au moins 4 cas Les shunts systémiques portaux spontanes qui ne se font pas par des varices oesophagiennes sont probablement plus frequents qu'on ne le pensait jusqu à maintenant

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HYOSCINE-N-BUTYLBROMIDE (BUSCOPAN) AS A DUODENAL RELAXANT IN TUBELESS DUODENOGRAPHY

G AYRE-SMITH

Duodenal morphology is difficult to demonstrate on the standard barium meal examination and hypotonic duodenography was therefore introduced by LIOTTA (1955) to demonstrate abnormalities of the duodenal loop more fully Duodenography was originally intended as a method for the early diagnosis of carcinoma of the head of the pancreas (BILBAO et coll 1968) This has not yet proved entirely successful (BENEDICT et coll 1970) and the use of this procedure now appears to be more confined to the evaluation of the duodenum where there is a doubtful abnormality on the standard barium meal examination (EATON & FERRUCCI 1973) and where there is a suggested abnormality in the perivaterian region (BENEDICT et coll) It is also used by some workers as a primary examination in suggested obstructive jaundice Its exact role in pancreatic disorders is not yet well defined

The interest is now centered around the accuracy of this technique in various pancreaticoduodenal disorders (EATON & FERRUCCI, EATON et coll 1968, BREE & FLYNN 1972, SHIRLEY 1974) and the evaluation of the various drugs which may be used in this procedure The anticholinergic agent propantheline bromide (Probantine) has become almost universally used as the agent of choice in intubated and tubeless duodenography (EATON & FERRUCCI, BILBAO et coll , MARTEL et coll 1969,

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EATON et coll 1970, FERRUCCI & BENEDICT 1971) However, recently it has been shown that parenteral glucagon is also an efficient duodenal relaxant (CHERNISH et coll 1972, MILLER et coll 1973, NOVAK & PROBST 1973, AYRE-SMITH et coll 1975)

Our preliminary results with glucagon in tubeless duodenography were not encouraging, however, (AYRE-SMITH et coll) and this combined with the fact that we and GOLDSTEIN & ZBORALSKE (1969) consider that the side-effects of propantheline have been understated, led us to undertake the present investigation

Materials and Methods

The purpose was not only to assess the efficacy of Buscopan for tubeless duodenography but also the most efficient route of administration and whether a follow through examination of the small bowel could subsequently be performed In addition, the onset and cessation of duodenal paralysis following the injection was timed

Forty-eight patients were used, 13 of whom were normal volunteers, the remainder having been referred for an upper gastrointestinal examination because of upper abdominal pain The patients were subjected to tubeless duodenography immediately after the barium meal was completed In addition, 43 patients had a follow-through examination at 1 hour, the remaining 5 patients had their films taken at the incorrect time and these follow-through films were not included No patient had had any drug which might have affected gastric or small bowel motility in the 24 hours immediately preceding the investigation

On the advice of the manufacturers the dosage of Buscopan used was 40 mg (2 ml) this being the recommended adult dose The patients were divided into 3 groups each group of 16 patients having the drug administered by a different route, group 1 intravenously as a bolus, group 2 intramuscularly, group 3 a combination of 1 ml intravenously followed immediately by 1 ml intramuscularly It was decided that the latter double route of administration should be included to assess whether a prolongation of the duration of action of the drug could be achieved, but at the same time achieving a relatively high initial blood level for rapid onset of duodenal paralysis

Technique The basic aim when the intravenous route is used (either singly or when combined with the intramuscular route) is to inject the drug only once adequate duodenal filling has occurred Gravity filling of the loop after injection, as advocated by some authors using Probanthine (MARTEL 1968, GOLDSTEIN & ZBORALSKE) is usually not successful and is not advised It is not always possible to obtain paralysis at the exact time that the loop is full of barium, but if it is attempted to anticipate a peristaltic wave propelling barium from the gastric antrum into the duodenal bulb, this is frequently possible, particularly bearing in mind that paralysis is induced in 30 to 45 s in most cases The technique requires some practice, but satisfactory results are almost always obtained especially if the patient is turned right side down from


Fig 1 Grade 1


Fig 2 Grade 2

the beginning and kept in this position until the duodenum is paralysed It is thus always advisable to have an intravenous indwelling needle inserted at the beginning of the examination Should the loop not be full of barium when paralysis occurs, this merely means that only double contrast views are obtained and not a combination of these and views with the duodenum full of barium If only double contrast views are obtained, this does not detract from the diagnostic value of the examination

Using the intramuscular route alone, the above technique is not possible as peristalsis may take 3 min or more to be arrested and the operator cannot therefore time his injection appropriately As before however, the injection is not given before the duodenal loop is filling adequately and once the injection has been given the patient is turned right side down to encourage duodenal filling by gravity

For both techniques the patient was given a mixture of 100 ml of a commercial barium sulphate preparation (Barosperse 60% W/V) and 40 gas producing tablets (Gastrast T) Following examination of the upper gastrointestinal tract, the patient was turned into the right lateral position Once adequate duodenal filling had been achieved the drug was injected and the onset of paralysis awaited Patients who had hypotonic stomachs were given more barium to drink When the loop was flaccid and filled with barium films were exposed in the oblique prone and oblique supine positions Turning the patient into the left lateral position allows gas to enter the duodenal loop so that double contrast views were possible However, gas distension



a



b

Fig 3 Grade 3 Two examples

of the loop is often most easily obtained by turning the patient from the supine left oblique to the prone right side down position The patient can then be turned back to the supine position for exposure Unfortunately the prone position is sometimes unsatisfactory for taking films of the loop as the barium filled gastric antrum may overlap the area of interest

Subsequent to exposure the patients were fluoroscoped at 15 s intervals to time the return of peristalsis In addition the patients were questioned and examined 10 min after injection for anticholinergic side effects

Results

The qualitative result was evaluated according to the scoring system used by AYRE-SMITH et coll , which is as follows

Grade 0 Inadequate views of the duodenal loop being obtained

Grade 1 The examination failed to add anything more than the previous barium meal (Fig 1)

Grade 2 More information was provided than the barium meal, but the degree of coating, barium distension and air contrast of the loop were not satisfactory (Fig 2)



Fig 4



Fig 5

Fig 4 Grade 4 Better coating and distension than in grade 3

Fig. 5 Score between 2 and 3 points (2½ points)

Grade 3 Adequate distension and gas contrast obtained, but the subjective quality not matching that of a standard intubation (Fig 3)

Grade 4 The tubeless examination produced results comparable to that of an intubation (Fig 4)

It was found that a few cases could not be assigned a score of 2 or 3 and fell between these two groups (Fig 5) These were arbitrarily assigned a score of 2½ points

For comparison a normal intubation view was provided to the scorer, an independent gastro-intestinal radiologist The results were also scored by the writer The tubeless duodenal view was considered successful only if a score of 3 or 4 was obtained (an excellent result) a score of 2½ points (a 'good result) was considered as a separate group in evaluating the results but were also regarded as successful

Other methods for evaluating the quality of the films have been used GOLDSTEIN & ZBORALSKE classified their results as excellent good or poor according to the degree of duodenal atony and distension and the quality of mucosal detail achieved NOVAK & PROBST used a hypotonic index for assessing their cases The follow through small bowel examinations were evaluated for the presence of any residual paralysis Note was also taken of the level in the small bowel which the barium had reached by

Table 1

Success rate of tubeless duodenography using Buscopan (48 patients)

Route of administration	No of patients with score of 3 or 4*	Percentage success**
Intravenous	12 (13)	75 (81 5)
Intravenous—intramuscular	12 (14)	75 (87)
Intramuscular	13 (14)	81 (87)
All routes combined	37 (41)	77 (85)

* Figures in brackets indicate success numbers if those with a score of 2½ are included

** No statistical difference exists between these results

1 hour The latter observation was only taken as an indication of the delay in the passage of the barium, bearing in mind that the time of the injection varied in each patient according to the time taken to complete the barium meal (which was never more than 12 min) and accordingly the barium had already reached different levels in the small bowel

The onset of paralysis in the loop was timed from the injection to the point at which no peristalsis was observed on fluoroscopy If peristalsis was not arrested the time taken to the point of maximum hypotonia was taken The cessation of paralysis was judged by the return of peristaltic waves in the duodenum, no matter how small in amplitude

The results were considered successful in 37 patients 77 per cent (all routes of administration, Table 1) Individual routes of administration were successful in 75 per cent of patients in the intra venous group, 81 per cent in the intramuscular group and 75 per cent in the combined route group If the group obtaining a score of 2½ points is included as successful, the total success rate rises to 85 per cent (all routes) There was excellent agreement in the scoring results of the scorer and the writer

Onset of paralysis a) In groups 1 and 3 the times varied between 20 and 120 s however paralysis was accomplished before 45 s in the majority of patients (78 per cent) No difference in the onset of paralysis in groups 1 and 3 existed, but in group 3 peristalsis was incompletely arrested in 3 patients, the times for maximum hypotonia to be achieved in these cases were similar to those where complete paralysis occurred b) In group 2 the times varied between 40 s and 7 min, the majority of cases (81 per cent) being between 3 and 5 min In 6 patients, however, peristalsis was not fully arrested, the average time for maximum hypotonia to be achieved again being similar to the cases where peristalsis was completely arrested

Duration of paralysis Group 1 this varied between 7 and 25 min, with an average of 16 9 min However, in 87 5 per cent of patients paralysis lasted *15 to 25 min* Group 2 of those in whom complete paralysis was obtained, peristalsis returned

Table 2

Comparison of the onset and duration of action of the various drugs used in duodenography

Drug	Time of onset of paralysis after injection (min)	Duration of paralysis (min)	Dose and route of administration IM = intramuscular IV = intravenous	Source
Probanthine	3–8	10–20	IM 30–60 mg	EATON & FERRUCCI
	3–4	8–10	IM 60 mg	GOLDSTEIN & ZBORALSKE
	5–8	10–20	IM 30–60 mg	FERRUCCI et coll
	3	15	IM 60 mg	LAWSON & MARGULIS
	—	26 4 ± 17 5	IV 15–30 mg	NOVAK & PROBST
	½–1	3 5	IV 30–60 mg	AYRE SMITH (unpublished)
Buscopan	3/4	16 9	IV 40 mg	Present series
	3 5	14 6	IM 40 mg	
	3 4	18 4 times widely scattered and unpredictable	IM + IV 20 mg each	
	—	15 4 ± 10 1	IV 60–80 mg	NOVAK & PROBST
Glucagon	1 min or more	15–20	IV 1 mg	AYRE SMITH et coll
	5–10	approx 30	IM 2 mg	MILLER et coll
	1/4 min or less	26 4 + 17 5	IV 1 2 mg	NOVAK & PROBST

between 8 and 25 min with an average of 14 6 min In only 50 per cent did paralysis last between 15 and 25 min *Group 3* peristalsis returned between 5 and 30 min with an average of 18 4 min (in those cases where paralysis was complete) In two thirds of the patients paralysis lasted 15 to 25 min (These results are summarised and compared with other series in Table 2)

The follow through examinations are summarised in Table 3 The relative levels which the barium reached are only approximate for reasons already explained No significant difference in the level reached or the residual abnormalities on the one-hour film was demonstrated between the various groups, but in only 33 3 per cent

Table 3

The effects of 40 mg of Buscopan on the follow through examination

Route of administration	Normal follow through examination) (per cent)	Minor abnormalities* (per cent)	Major abnormalities** (per cent)
Intravenous	43	35 5	21 5
Intravenous—intramuscular	19	56	25
Intramuscular	40	26 5	33 5
Average of all routes	33 3	40	26 7

* Slight hold up of barium column (not reached beyond proximal ileum by 1 hour) slight aperistalsis (Fig 6)

** Marked aperistalsis and hold up of barium (Fig 7)

of patients was the small intestine (including the duodenum) considered as having returned to normal The range of abnormalities was however wide and ranged from marked residual paralysis and hold up of barium passage (Fig 7) to minimal aperistalsis, particularly in the duodenal loop (Fig 6) It is noteworthy that in 3 patients who mistakenly had films taken at 2 hours, the effect of the drug appeared to have worn off completely

Discussion

Tubeless duodenography is a well-established procedure for the examination of pancreaticoduodenal lesions Although the technique is simple and produces adequate films of the duodenum in 85 to 92 per cent of cases (MARTEL et coll , EATON & FERRUCCI, GOLDSTEIN & ZBORALSKE), there is no doubt that the intubated examination gives uniformly more elegant views and in a higher percentage of patients is the examination successful The intubated examination is therefore still advocated by most authors (BENEDICT et coll) Maximum distension of the duodenum in its entirety with a clear demonstration of the anatomy is achieved in virtually all cases The distension is claimed to demonstrate a larger pancreaticoduodenal interface and to increase the chance for detecting subtle pancreatic pathology (EATON & FERRUCCI) and some authors (JACQUEMET et coll 1965) consider the tubeless examination less reliable, although this is not proved In the writer's view, however, the distension achieved may in fact disguise subtle abnormalities of the duodenum, and no controlled comparison of tubeless and intubated duodenography has yet been published to show that the latter examination is the more accurate In fact MARTEL et coll and FERRUCCI & BENEDICT have both cautioned that abnormal folds may be obscured and have advised close correlation of the intubated examination with the standard barium meal



Fig 6



Fig 7

Fig 6 A follow through examination of the small bowel 1 hour after parenteral administration of 40 mg of Buscopan Minor abnormality, i e slight hold up of the passage of barium and relative aperistalsis (especially of the duodenal loop)

Fig. 7 A follow through examination after Buscopan administration Major abnormality Marked hold up of the barium

The standard utilization of tubeless duodenography is following the conventional barium meal when an unusual duodenal configuration is seen in the initial films, or if it is omitted at this stage, its use is reserved should duodenal intubation fail (EATON & FERRUCCI) Our feeling is, however, that tubeless duodenography should be performed in all cases that require duodenography, as a successful examination may save the patient intubation This latter view is shared by MARTEL et coll and GOLDSTEIN & ZBORALSKE and indeed the former believe that intubation is rarely called for Should the radiologist however feel that subsequent intubation is advisable, the tubeless examination provides a most useful adjunct to the intubation films Regarding the use of duodenography following the standard barium meal, it should be observed that a follow through examination of the small bowel is not possible when Probanthine is used, and is only possible in one third of the patients when using Buscopan

Buscopan has received scant attention except in the Continental literature KRIESSMAN (1968) has commented favourably on its use in intubated duodenography, and MURRAY (1966) found it to be a safe and effective spasmolytic in assessing achalasia

of the cardia, prepyloric ulceration, and functional and organic disorders of the colon NOVAK & PROBST using high doses of Buscopan (60 to 80 mg) intravenously have reported on the relative merits of Buscopan, glucagon and Probarthine in tubeless duodenography They favoured glucagon because of its lower incidence of side-effects and longer duration of action (26 4 min) compared to Buscopan (15 4 min) They also reported that the onset of action of glucagon was 5 to 15 s MILLER et coll have investigated the efficacy of 2 mg of glucagon given intramuscularly by contrasting its effects on duodenal motility and tonicity, and its side-effects with those of atropine, probanthine and a placebo They concluded that glucagon produced a far lower incidence of side-effects, and had a greater hypotonic effect which lasted longer than the other drugs (usually about 30 min, with an onset of action of 5 to 10 min) They therefore concluded that glucagon was more effective and preferable to the other drugs Using the drug intravenously they reached similar conclusions regarding its efficacy in duodenography However, the degree of hypotonia was investigated rather than the quality of the films, and this may explain the discrepancy on their results with that of AYRE-SMITH et coll The latter, using 1 mg of glucagon intravenously found it to be less satisfactory than Buscopan achieving a success rate of only 53 per cent with an onset of action of 1 min or more and a duration of action of 15 to 20 min They ascribed their low success rate to an inability to fill the duodenum with barium or gas once the drug had been injected, an effect which may have been due to pyloric closure The effect of glucagon on the pyloric musculature is however controversial at present (HRADSKY et coll 1973) Further work on this drug in duodenography is required, and the optimum route of administration, the technique of the examination and dosage need to be elucidated

The high incidence of side-effects using Buscopan reported by NOVAK & PROBST was not confirmed in the present series, this almost certainly being due to the far lower dosage used (40 mg, compared to 60 to 80 mg) This low incidence (2 out of 48 patients) in fact surpasses that of glucagon, MILLER et coll recording a total of 16 reports of side-effects in 12 patients

Buscopan itself is a quarternary ammonium synthesized from scopolamine It is a ganglion-blocking agent, having no central action (unlike scopolamine), and causes only minor atropine-like side-reactions unless doses of over 40 mg are employed (WRIGHT 1961) The higher doses as favoured by some authors (KRIESSMAN, NOVAK & PROBST) lead to a significant incidence of side-effects such as dryness of the mucous membranes, mydriasis, palpitations, nausea and headaches Buscopan has its main action on the parasympathetic-innervated visceral organs which contain smooth muscle, hence its marked effect on the gastro-intestinal tract

Probanthine is widely used for duodenography especially in North America, but it has a high incidence of side-effects (FERRUCCI & BENEDICT) and its use is contraindicated in patients with glaucoma, significant cardiac disease (especially when an arrhythmia or severe angina is present) and in prostatism (BILBAO et coll , EATON & FERRUCCI) In order to avoid the side-effects, the drug has been used in various dos-

age regimes of between 15 and 60 mg and by various routes of administration The most experienced authors recommend 30 to 60 mg intramuscularly, claiming that this route of administration gives a reduction in side-effects whilst at the same time achieving adequate hypotonia (EATON & FERRUCCI) At this dosage using the intramuscular route paralysis is not always complete however, and before the routine use of Buscopan in our unit, up to 60 mg of Probanthine was used intravenously in order to obtain complete paralysis of the duodenum Probanthine is without doubt an inferior agent to Buscopan due to its high incidence of side-effects, although the hypotonic effect is comparable to that of the latter drug In addition, an added advantage of Buscopan is that the duration of action is slightly longer especially if the drug is given intravenously (Table 1)

Following the disappointing results with glucagon in tubeless duodenography and the present results, Buscopan appears to be the drug of choice in this examination, and its efficacy would therefore undoubtedly extend to the intubated examination as well

Conclusions

(1) Buscopan has proved a highly successful drug in the tubeless examination of the duodenum, with a success rate of between 77 and 85 per cent

(2) The drug is safe and free from side-effects, only 2 out of 48 patients (4 2 per cent) complaining of transitory blurring of vision No other atropine-like side-effects were encountered, but one third of patients exhibited a transient tachycardia (up to 110 beats per min)

(3) The examination is most efficiently performed by the intravenous route with a dosage of 40 mg, although no significant difference is statistically present between the scores obtained by each individual route The other routes of administration both had disadvantages as follows (a) The intramuscular route has a slightly shorter duration of action, furthermore it produces incomplete paralysis in a high percentage of patients The long interval (3 min) between the time of the injection and the onset of paralysis is also inconvenient (b) The combined route is inconvenient for the operator and painful for the patient as it requires two injections The average duration of paralysis (18 4 min) is longer than the other two routes, but in practice the times are unpredictable and vary widely The failure to achieve the high initial blood levels of the drug which the purely intravenous route provides also does not provide complete paralysis in all patients It is felt that complete paralysis is desirable in duodenography because the presence of peristaltic waves adds unnecessary difficulties to the examination in that the exposure of the film has to be judiciously timed in order to 'catch' the duodenal loop in its distended state It is also diagnostically more accurate and permits better delineation if the loop is completely aperistaltic (FERRUCCI & BENEDICT)

(4) The examination is likely to be unsuccessful in the following circumstances (a) If the stomach is hypotonic, precluding adequate filling of the duodenal loop and (b) where the barium filled gastric antrum overlaps the duodenum, and where

the loop cannot thus be projected free (LAWSON & MARGULIS 1969), this was encountered in 15 of our cases (31 per cent)

(5) The follow-through examination is only possible in a small percentage of patients (33 3 per cent overall, i e all routes of administration) Slight abnormalities (relative aperistalsis, slight hold-up of the barium, i e filling of proximal ileum but not the mid- or distal ileum at 1 hour), were encountered in 40 per cent of patients

(6) Buscopan (77 per cent success rate in 48 patients) was a more efficient agent in tubeless duodenography than glucagon (Glucagon-Lilly) with a 53 per cent success rate in 21 patients The differences are statistically significant at the 10 per cent level ($p > 0\ 05$, $< 0\ 01$)

SUMMARY

The efficacy of Buscopan in tubeless duodenography was tested in 48 patients using different routes of administration The drug led to successful results in 77 to 85 per cent of patients in the dosage used (40 mg), the intravenous route proving the most efficient The drug is considered superior to Probanthine and glucagon (Glucagon Lilly) in view of its safety, low incidence of side effects and efficacy Follow-through examinations of the small bowel at 1 hour are possible in 33 per cent of patients, although 40 per cent have mild residual abnormalities only

ZUSAMMENFASSUNG

Es wurde die Wirksamkeit von Buscopan bei der Duodenographie ohne Sonde bei 48 Patienten unter Anwendung verschiedener Formen der Administration gepruft Die Substanz fuhrte zu erfolgreichen Ergebnissen in 77 bis 85% der Patienten bei der verwendeten Dosis (40 mg), wobei sich die intravenose Verabfolgung als am wirksamsten erwies Die Substanz erwies sich gegenuber Probanthin und Glukagon (Glucagon Lilly) hinsichtlich ihrer Sicherheit, niedrigen Vorkommens von Nebenwirkungen und Wirksamkeit als uberlegen Abschliessende Untersuchungen des Dunndarms in einer Stunde sind nur bei 35% der Patienten moglich, obwohl nur 40% geringfugige Rest-Abnormalitaten hatten

RÉSUMÉ

L'auteur a étudié sur 48 malades l'efficacité du Buscopan administré par differentes voies dans la duodénographie sans tubage Ce produit a donné de bons résultats dans 77 à 85% des cas, au dosage utilisé (40 mg), la voie intra-veineuse se montrant la plus efficace Du point de vue de l'innocuité, le Buscopan est considéré comme supérieur à la Probanthine et au glucagon (Glucagon-Lilly) L'examen de l intestin grêle au bout d'une heure n'est possible que chez 35% de ces malades, bien 40% des malades n'aient que de légères anomalies résiduelles

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GASTRIC MOTILITY AND EMPTYING FOLLOWING PARIETAL CELL VAGOTOMY AND SELECTIVE GASTRIC VAGOTOMY

Experimental investigation

KIRSTEN MIKKELSEN, P O ERIKSEN and J BONÉ

In recent years, selective gastric vagotomy and parietal cell vagotomy (also called highly selective vagotomy or proximal gastric vagotomy) have been increasingly used in the treatment of duodenal ulcer By the former method, reduction of acid secretion is achieved by cutting all branches of the vagal nerves to the stomach keeping the extragastric vagus intact This procedure is ordinarily combined with pyloroplasty By parietal cell vagotomy, only the parietal cell mass is denervated, and the innervation of the muscular gastric antrum is preserved The clinical results in some series (AMDRUP & GRIFFITH 1969, AMDRUP & JENSEN 1970, WILBUR & KELLY 1973) seem to indicate that a drainage is not a necessary supplement to parietal cell vagotomy while other authors (KLEMPA 1971, HOLLE et coll 1972) claim that this has to be added As the drainage procedure may result in dumping symptoms, the question of its necessity is important

The present animal experiments aim at assessing the influence of the two methods and a drainage procedure upon gastric motility of a meal normally taken by the experimental animals The intention was also to examine the influence of the operations on the hormonal phase of gastric secretion Therefore, a denervated fornix pouch, i e a Heidenhain pouch, was constructed in all dogs and the influence of this operation on gastric emptying and motility was also assessed

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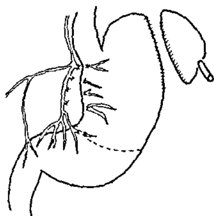


Fig 1 Technique of parietal cell vagotomy in a dog with a Heidenhain pouch Dotted line indicates the border between corpus and antrum

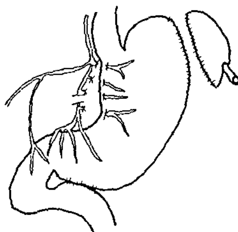


Fig 2 Technique of selective gastric vagotomy in a dog with a Heidenhein pouch and gastroduodenostomy

Material and Methods

Adult, healthy mongrel dogs were used and the gastric motility was recorded (1) before and after application of a Heidenhain pouch, (2) after parietal cell vagotomy without drainage, (3) after application of a gastroduodenal anastomosis (method of Jaboulay) and (4) after altering the parietal cell vagotomy into a selective gastric vagotomy by cutting the antral nerves

Another series of dogs with a Heidenhain pouch was investigated before and after selective gastric vagotomy without a drainage operation

All procedures were performed under pentobarbital (Nembutal) anaesthesia (30 mg/kg intravenously) In all the dogs a Heidenhain pouch was first constructed according to the method of DE VITO & HARKINS (1959) On performing the parietal cell vagotomy, an intragastric pH electrode was used to determine the border between the corpus and the antrum after stimulation of acid secretion with 0 25 mg pentagastrin (Peptavlon) administered intramusculary 20 min before operation The branches of the anterior and posterior gastric nerves were then sectioned from the border between the corpus and antrum to the gastroesophageal junction which was carefully skeletonized' circumferentially of all small vagal branches (Fig 1) In selective gastric vagotomy the anterior and posterior gastric nerves were cut just below the left gastric artery The remaining part of the stomach was denervated by the technique used in parietal cell vagotomy (Fig 2) The gastroduodenal anastomosis was constructed between the distal part of the antrum and the upper part of the duodenum The stoma was placed 1 to 2 cm from the pylorus and was 4 cm wide Examinations were not started until 3 to 4 weeks following surgery

The gastric emptying rate was recorded by fluoroscopy 3 times for each dog after

Table 1

Gastric emptying and motility before and after application of a Heidenhain pouch In this and in the following tables gastric emptying time is the mean of 3 experiments in each dog

	Dog No	Waves per min	Strength	Peristaltic waves	Emptying time (min)
Before operation	A 10	5–6	3	+	217
	A 11	5	3	+	200
	A 12	5	3	+	147
	A 13	5–6	3	+	199
	A 14	6	3	–	260
	A 15	6	2	+	297
					220 ± 52 36 (mean)
After operation	A 10	?	3	–	279
	A 11	4	3	+	175
	A 12	4–5	2		162
	A 13	6	2	+	126
	A 14	6	3	+	133
	A 15	4–5	2	+	179
					176 ± 55 06 (mean)

+ All effective

Table 2

Gastric emptying and motility before and after application of partial cell vagotomy (PCV)

Operation	Dog No	Waves per min	Strength	Peristaltic waves	Emptying time (min)
Heidenhain pouch	A 11	4	3	+	175
	A 14	6	3	+	133
	A 24	5	3		130
	A 25	5	3	+	163
	A 26	?	2	+	155
	A 28	5	3	+	150
					151 ± 17 33 (mean)
Heidenhain pouch + PCV	A 11	5	3	+	170
	A 14	6	3	+	148
	A 24	5	3	+	192
	A 25	4	2	–	222
	A 26	?	2	+	158
	A 28	5	3	+	152
					173 ± 28 80 (mean)

+ All effective
– Some ineffective

Table 3

Gastric emptying and motility before and after application of parietal cell vagotomy (PCV) and Jaboulay anastomosis (GD)

Operation	Dog No	Waves per min	Strength	Peristaltic waves	Emptying time (min)
Heidenhain pouch	A24	5	3	–	130
	A25	5	3	+	163
	A26	[illegible]	3		155
	A28	5	3	+	150
	A29	5	3	+	143
	A31	6	3	–	133
	A32	5	3	+	135
	A33	5	3		117
					141 ± 14 99 (mean)
PCV – GD	A24	18	1	+	122
	A25	20	1	–	110
	A26	15	1	–	117
	A28	[illegible]	0	+	147
	A29	10	2	+	110
	A31	8	1	+	115
	A32	10	1	+	110
	A33	20	1	+	215
					131 ± 35 96 (mean)

All effective
Some ineffective

each of the mentioned operations After 18 hours of fasting the dogs were given 200 g of standard dog food (in 100 g 9 g of protein, 3 g of fat, and 7 g of carbohydrate) with 75 ml barium sulphate added The stomach was considered empty when only a slight mucosal coating persisted At the first examination the dogs were placed on the screening couch, 5, 15, 30, 45, 60, 90 and 120 min after the meals and a videotape was recorded At the two following examinations they were screened at 60, 90, 120 min and until the moment of emptying

Evaluation of motility was later made by replaying the videotape (method of LAGEMANN & HOFFMANN 1971) Assessments were made according to the following scheme (1) frequency of peristaltic contractions measured as waves per min, (2) intensity of the peristaltic waves, equalling the superficial contraction as force 1, medium deep as force 2, and the extra deep hour-glass shaped contractions as force 3, no peristalsis as 0, and (3) effect of the peristalsis indicated by the number of contractions emptying some of the gastric content into the duodenum

Results of the emptying rate are given in min as mean ± SD The significance of mean differences was estimated with Student's t test for paired values

Table 4

Gastric emptying time before and after altering the parietal cell vagotomy and anastomosis (PCV + GD) into a selective gastric vagotomy and anastomosis (SGV + GD). Gastric motility ceased completely after selective gastric vagotomy.

Dog No.	Emptying time (min)	
	PCV + GD	SGV + GD
A 24	122	115
A 25	110	100
A 26	117	95
A 28	147	112
A 29	110	60
A 31	115	152
A 32	110	147
A 33	215	202
Mean	131 ± 35.96	123 ± 43.30

Results

Generally the peristalsis started about 15 min after the meal. The behaviour of the stomach remained unaltered within the first hour, then the peristalsis tapered slowly. As in man, the fornix of the stomach only made slight movements, whereas peristalsis occurred in the intact antrum propelling the gastric content into the duodenum.

After application of a Heidenhain pouch. Six dogs were used (Table 1). Only a slight alteration of the force of the contractions occurred in 2 of the dogs (A 12 and A 13). The mean emptying time for the group decreased, but insignificantly from 226 ± 52.36 to 176 ± 55.05 min.

After parietal cell vagotomy. Six dogs were used (Table 2). The stomach appeared as before the operation. The strength of the contraction of the peristaltic waves was unchanged except in dog A 25. A non-significant increase in the mean emptying time from 151 ± 17.33 to 173 ± 28.80 min occurred in this group.

After parietal cell vagotomy and gastroduodenal anastomosis. Eight dogs were used (Table 3). Previously, 4 of them had a parietal cell vagotomy without anastomosis (A 24, A 25, A 26, A 28). After the operation the barium passed mainly through the anastomosis and only to a small degree through the pylorus. The strength of the contractions decreased in all of the dogs while the number of peristaltic contractions increased. However, as compared to the control group, mean emptying time for the whole group decreased insignificantly from 141 ± 14.99 to 131 ± 35.96 min. Even if

Table 5

Gastric emptying time in dogs with a Heidenhain pouch before and after application of selective gastric vagotomy without anastomosis Gastric motility ceased completely after the vagotomy

Dog No	Empyting time (min)	
	Before operation	After operation
A7	225	480
A34	153	460
A36	207	440
A43	140	350
Mean	181 ± 41 13	433 ± 57 37

the dogs with previous parietal cell vagotomy are considered separately, no significant alteration occurred

After selective gastric vagotomy and gastroduodenal anastomosis The same 8 dogs as in the last section were used (Table 4) After cutting the antral nerves the stomach in all the dogs appeared like a big, slack bag, emptying through the anastomosis only No peristalsis was observed The emptying time decreased insignificantly from 131 ± 35 96 to 123 ± 43 30 min

After selective gastric vagotomy without drainage Four dogs were used (Table 5) After the operation the stomach appeared big, slack and atonic as in the foregoing group but the emptying time was significantly delayed from 181 ± 41 13 to 433 ± 57 37 min ($p < 0\ 005$)

Discussion

The methods for investigation of the gastric emptying rate are numerous plastic spheres were used by WILBUR & KELLY (1973), liquid meals with contrast medium added by AMDRUP & GRIFFITH (1969), scintigraphy by WICKBOM et coll (1971) and aspiration by BUCKLER (1967) The results differ widely, however

The examining conditions must be as identical as possible to the normal The contrast medium added to the meal should not interfere with the determinations of the various parameters under assessment The contrast medium used seems to fulfil these requirements Less physiologic contrast meals have been used in some previous investigations There seems to be no report available on the significance of a Heidenhain pouch on gastric motility and emptying The present results indicate that the pouch does not alter the emptying rate or motility

Following selective gastric vagotomy the stomach became dilated and slack with complete atony The meal was propelled only passively and slowly through the pylorus, resulting in a protracted retention of the meal in the stomach Following a

gastroduodenostomy, the emptying time was reduced as the contrast passively passed through the anastomosis

After parietal cell vagotomy, the size and shape of the stomach were normal the strength and number of the contractions were unaltered and the emptying time was insignificantly delayed On the other hand, AMDRUP & GRIFFITH in dogs with a Heidenhain pouch using a homogeneous mixture of evaporated milk, barium sulphate and water observed a non-significant increase in the stomach emptying rate Similar results were reported by WILBUR & KELLY who in dogs without a Heidenhain pouch employed solid plastic spheres If a difference exists between the present results and the two reports mentioned, this may be explained by the difference of the type of meal used, in the present experiments being a normal dog meal, non homogeneous and semisolid The present results agree with those of clinical examinations, in which similar types of physiologic meal and added contrast medium were employed (BRANDSBORG et coll 1975)

Contrary to this, KLEMPA et coll (1971) using colloidal barium sulphate found a significantly prolonged gastric emptying after parietal cell vagotomy in dogs with a Heidenhain pouch This discrepancy may be explained by differences in the operative procedure In the present experiments the pH electrode was used for the determination of the border between the antrum and the corpus It was in all dogs identified about 2 cm proximal to the border indicated by the anatomy of the nerves and used by KLEMPA et coll It is likely that the prolonged gastric emptying time after their operation was caused by the more extensive denervation of the antrum With reference to the results of KLEMPA et coll, HOLLE et coll claim that a drainage procedure always has to be performed together with parietal cell vagotomy The present results indicate that emptying is normal after parietal cell vagotomy while the addition of a drainage procedure changes the motility with a considerable reduction in the intensity of the gastric contractions, presumably because the meal is passively transported through the anastomosis This results in a more rapid emptying which in man may *lead to 'dumping'* *In conclusion it may be said that parietal cell* vagotomy does not affect the gastric motility and emptying but that this procedure with drainage and selective gastric vagotomy with or without drainage affect both the motility and emptying The results achieved in animal experiments indicate that parietal cell vagotomy without drainage is the procedure of choice

SUMMARY

After parietal cell vagotomy in dogs antral motility and gastric emptying time is unaffected [illegible]

nerves complete atony occurred, but emptying rate was unaltered as the contrast [illegible] passively through the anastomosis Selective gastric vagotomy without drainage caused atony and significantly prolonged emptying time

ZUSAMMENFASSUNG

Nach parietaler Zellvagotomie war die Motilität des Antrums und die Entleerungszeit des Magens von Hunden nicht beeinflusst Ein zusätzliches Drainageverfahren veränderte die Motilitat durch einen Abfall der Kraft der Kontraktionen und eine verminderte Zahl von peristaltischen Wellen beträchtlich Nach Abschneiden der Nerven des Antrums trat eine vollständige Atonie auf Jedoch war die Entleerungsgeschwindigkeit unverändert, wenn die Kontrastmahlzeit passiv durch die Anastomose befordert wurde Eine selektive Vagotomie des Magens ohne Drainage verursachte eine Atonie und eine signifikant verlangerte Entleerungszeit

RÉSUMÉ

La motilite antrale et la duree de l'evacuation gastrique ne sont pas modifiees apres vagatomie cellulaire pariétale chez des chiens L'association d une technique de drainage modifie considérablement la motilité en diminuant la force des contractions et en diminuant le nombre des ondes peristaltiques Apres section des nerfs antraux apparait une atonie complète mais la vitesse d evacuation est inchangee car le repas baryte passe passivement a travers l'anastomose La vagotomie gastrique sélective sans drainage entraîne une atonie et une prolongation importante de la durée d evacuation

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XERORADIOGRAPHY AND CONVENTIONAL RADIOGRAPHY IN EXAMINATION OF THE LARYNX

ANDERS HEMMINGSSON and PER OLOV LÖFROTH

Xeroradiography has been recommended for radiography of the larynx in the lateral projection by WOLFE (1969) and HOLINGER et coll (1972), among others, and in the a p projection combined with linear tomography by DOUST & TING (1974) WOESNER et coll (1974) have advocated a combination of xeroradiography and circular zonography, with an exposure time of 3 2 to 4 0 s, for a p examination of the larynx Neither linear tomography nor zonography allow a satisfactory evaluation of the laryngeal structures in the frontal view, however, due to the long exposure time and the interfering blur from the cervical spine (HEMMINGSSON 1972) It has not been established, on the other hand, whether conventional xeroradiography is an adequate method for replacing or complementing conventional radiography with contrast medium for examination of the larynx Therefore, a comparison was performed between the perceptibility of simulated laryngeal lesions in conventional radiography and xeroradiography in the a p projection of phantoms with and without contrast medium The use of positive and negative film processing in xeroradiography was also compared

In 12 patients a comparison was made between the perceptibility of the laryngeal structures in conventional radiography and xeroradiography in the lateral projection Only 5 patients were examined with both techniques in the a p projection because of the high radiation dose

In addition the radiation doses in conventional radiography and xeroradiography were measured and compared in the frontal and lateral projections

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Table 1

Exposure data at 50 to 175 kV in a.p. conventional radiography and xeroradiography of the cervical phantom. Field size 5 cm × 9 cm

Tube potential (kV)	Conventional radiography		Xeroradiography		Exposure ratio xeroradiography/ conventional radiography
	mAs	Exposure (mR)	mAs	Exposure (mR)	
50	200	271	1 500	2 000	7
75	20	66	250	828	13
100	6.4	38	130	764	20
150	1.6	23	50	710	31
150 + 1 mm brass	4.0	16	200	775	50
175	1.0	20	32	629	31
175 + 2 mm brass	4.0	16	320	1 250	81

Material and Methods

Phantom experiments. A cervical phantom consisting of a cervical spine embedded in the soft-tissue equivalent phantom material Mix D (HEMMINGSSON 1971) was used. For examinations without contrast medium, pellets of Mix D with diameters of 6, 8 and 10 mm were introduced into the bore hole simulating the laryngeal cavity in the phantom, and for examinations with contrast medium a thin layer of Dionosil suspension (Glaxo) was applied to pellets of Mix D with diameters of 2, 3 and 4 mm. Universal screens (Siemens) and Vicor-X film (Cea) were used at conventional radiography. Xeroradiography (Rank Xerox S-125) was performed with the selenium plate charged at different settings and with positive or negative processing. When negative processing was used, the different 'densities' B, C and D were compared. Exposures were made with an a.p. beam direction with tube potentials varying from 50 to 175 kV and with a constant anode current of 100 mA, while the exposure time was varied in order to obtain the same film density at the different potentials (Table 1). A tungsten tube with 2 mm inherent filtration was used. The focal spot was 1.2 mm × 1.2 mm, the focus-film distance 135 cm and the object-film distance 20 cm. Grid with a ratio of 7 was used. An equivalent film density for roentgenograms and xeroradiograms was achieved by making several exposures with different amperages at each tube potential, the films with comparable density were then selected.

Clinical examinations. In 12 patients conventional radiography and xeroradiography were performed in the lateral projection during respiration, before and after the application of contrast medium (Dionosil) in the larynx. The exposure data were 55–60 kV and 4.0 mAs for conventional films, 130 kV and 0.6 mAs for contrast laryngography with an ordinary technique, and 130 kV and 20 mAs for xeroradio-

Table 2

Entrance dose at conventional radiography and xeroradiography in clinical examination of the larynx

Technique	mAs	Dose (rad)	Dose (rad) complete examination (*10 exposures*)
Conventional radiography			
A p projection 150 kV + 1 mm brass	4 0	0 015	0 15
Lateral projection, 130 kV	0 6	0 019	0 19
Lateral *projection, 55–60 kV*	*4 0*	*0 050*	*0 05**
Xeroradiography			
A p projection, 150 kV + 1 mm brass	100	0 37	3 7
Lateral projection, 130 kV	20	0 62	6 2

* One exposure

graphy (Table 2) The focal spot was 0 6 mm × 0 6 *mm, the focus-film distance 110* cm and the object-film distance 35 cm No grid was used

In the a p projection the examination was performed as a laryngography with contrast medium (Dionosil) The exposure data were 150 kV + 1 mm brass filter and 4 0 mAs for conventional radiography and 150 kV + 1 mm brass and 100 mAs for xeroradiography *(Table 2) The focus film* distance was *120* cm and the object film distance 20 cm No grid was used

Dose determinations A Farmer ionization chamber (type 2505/3) with a volume of 0 7 cm^3 was used for determining the exposure in the phantom experiments *Measurements* were made in the *centre of the field* at the same focus-chamber distance both free in air and on the surface of the phantom at different tube potentials The results of the exposure measurements on the phantom surface appear in Table 1

The entrance dose in examinations of patients was *determined* [illegible] were calibrated at the relevant tube potentials

The measurement precision in the different exposure determinations was 2 to 3 per cent The calibration factors used *for the* ionization chamber had a maximum error up to 10 per cent, which meant that the absolute values for exposure and absorbed dose may have an error of that magnitude

Results

Phantom experiments In examinations without contrast medium the perceptibility of the pellets in the phantom was better at conventional radiography than at xeroradiography It improved with increasing tube potential and *filtration up to 150*

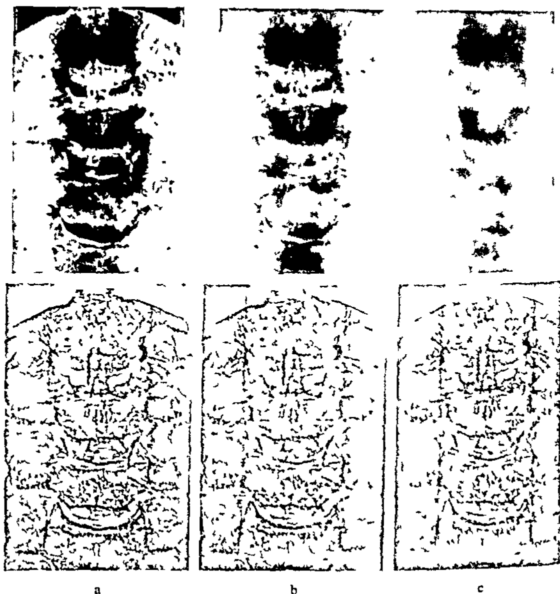


Fig 1 Conventional radiography (upper row) and xeroradiography (lower row) at a) 50 kV b) 100 kV and c) 150 kV + 1 mm brass Pellets (Mix D) 6 8 and 10 mm in diameter without contrast medium in the laryngeal cavity of the cervical phantom

kV + 1 mm brass for both systems Thus, at conventional radiography the outlines of all three pellets were visible at 150 kV + 1 mm brass, while they were practically imperceptible at lower tube potentials and at xeroradiography (Fig 1) The interfering image of the skeletal structures of the cervical spine became less evident with increasing tube potential and extra filtration at conventional radiography, while it was influenced only little by the tube potential at xeroradiography Thus, at the latter examination the bone structure was easily discernible even at 150 kV + 1 mm extra brass filtration, due to the edge enhancing effect of the system The charging of the selenium plate had no influence on the perceptibility

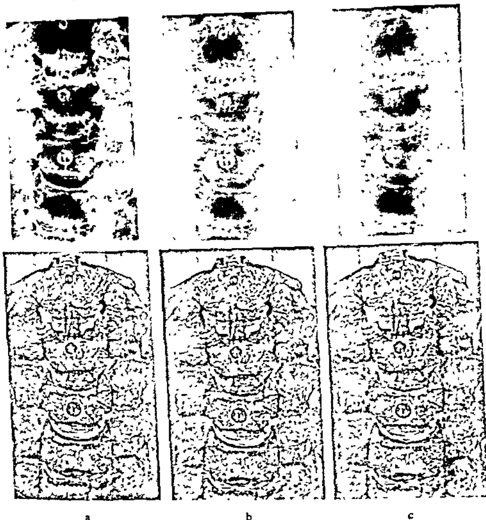


Fig. 2 Conventional radiography (upper row) and xeroradiography (lower row) at a) 50 kV, b) 100 kV and c) 150 kV + 1 mm brass. Pellets (Mix D), 2, 3 and 4 mm in diameter, coated with positive contrast medium in the 'laryngeal cavity' of the cervical phantom.

The pellets coated with contrast medium in the phantom were easily perceived both at ordinary radiography and at xeroradiography at all tube potentials (Fig 2). However, due to the fact that the radiation contrast of the skeletal structures at xeroradiography was of approximately the same magnitude as that of the contrast-coated pellets, it was somewhat difficult to distinguish between these pellets and the skeletal structures in the xeroradiograms

When positive processing was used at xeroradiography, the size of the contrast-coated pellets was approximately the same as at ordinary conventional radiography

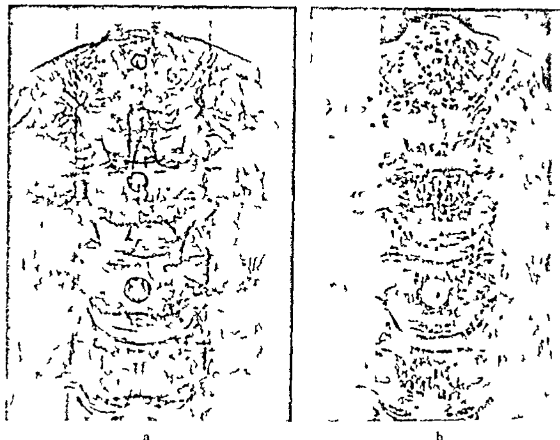


Fig 3 Xeroradiography of the cervical phantom with contrast-coated pellets in the laryngeal cavity Selenium plate charged at setting C a) Positive and b) negative processing with process setting at D

and corresponded with their true size when correction was made for geometric magnification (Fig 2) When negative processing was used on the other hand the diameter of the pellets was about 1 mm larger in the negative than in the positive xeoradiogram and the perceptibility of their outlines was poorer with negative processing (Fig 3) The use of different densities in the processing did not alter this finding

Clinical examinations In three of the 12 patients the visibility of the inner surface of the larynx the laryngeal cartilages and the surrounding structures in the *lateral* view was better at xeroradiography than at conventional radiography with a low tube potential when contrast medium was not used (Figs 4 a c 5 a b) Ordinary positive contrast examination with a high tube potential (130 kV) however invariably gave more information about the inner surface of the larynx than xeroradiography without contrast (Fig 4 b c) At xeroradiography with contrast medium in the lateral projection the perceptibility of the inner surface of the larynx was approximately the same as at ordinary radiography with contrast medium in all cases (Fig 4 b d)



Fig 4 Conventional radiography at a) 55 kV and b) 30 kV and c d) xeroradiography at 130 kV of a normal case in the lateral projection Contrast medium has been instilled in b) and d)

On comparison between xeroradiography and conventional radiography in the a p view with contrast medium no clear difference was found between the methods in any of the 5 patients

Dose determinations In the phantom examinations in the a p projection the exposure was greater at xeroradiography than at ordinary radiography (Fig 6, Table 1) It decreased with increasing tube potential for both systems, but the decrease was smaller at the former than at the latter The exposure was further reduced in ordinary radiography, but not in xeroradiography, by the use of extra filtration at 150 and 175 kV At the lower tube potentials of 50 and 75 kV the exposure was about 10 times higher at xeroradiography than at conventional radiography (Table 1) The difference increased with increasing tube potential and extra filtration, and at 150 kV + 1 mm extra brass, which is the technique generally used in frontal laryngography, the exposure was about 50 times higher at xeroradiography than at conventional radiography The ratio between the exposure at conventional radiography and xeroradiography at different potentials measured on the surface of the phantom corresponded to those made free in air

When the sensitivity of the xeroradiographic system was maximized by charging at setting D and *negative* processing at D, at the lower tube potentials an approximately 20 per cent lower exposure was obtained than with charging at B and positive processing whereas at 150 and 175 kV with extra filtration no difference was found

The entrance dose *in clinical* radiography of the larynx was about 30 times higher at xeroradiography than at conventional radiography both in the a p and in the lateral projection (Table 2) Table 2 gives the entrance dose for a complete examination of the larynx with the generally used technique (HEMMINGSSON 1972) comprising 10 p a and lateral views with *different* manoeuvres and also for a lateral view with a low tube potential at conventional radiography



Fig 5 a) Conventional radiography at 55 kV and b) xeroradiography at 130 kV in a 49 year-old man with a trauma (table edge) to the front of the neck Cranial subluxation of the thyroid cartilage, with rupture of the cricothyroid membrane The air in the soft tissues anterior to the larynx and the cartilages are better perceived at xeroradiography

Discussion

The reason why the contrast-coated soft tissue equivalent pellets are better perceived at higher tube potentials and extra filtration in conventional radiography is that the radiation contrast of the pellets is reduced much less than that of the skeletal structures with increasing energy, i e the higher the energy, the higher the signal noise ratio of the pellet to the skeletal structure (HEMMINGSSON & LUNDQVIST 1972, HEMMINGSSON 1972) At xeroradiography the radiation contrast of the skeletal structures decreases very little with increasing tube potential on account of the edge enhancing property of the system which explains why the pellets are less visible at xeroradiography than at ordinary radiography in other words the signal noise ratio of pellet to skeletal structure is higher for the latter system This means that an edge enhancing system of the xeroradiography type is often not suitable for roentgen examination of soft tissue structures when spongy bone is present in the beam unless contrast medium is used

When contrast medium was applied to the pellets in the laryngeal cavity of the phantom, even the smallest pellet, with a diameter of 2 mm, was clearly visible both at xeroradiography and at conventional radiography at all tube potentials The pellets were less easily perceived at xeroradiography than at conventional radiography, due to the fact that the interfering blur from the cervical spine was more marked with the former method Thus there is no advantage in using this system in examination of the larynx in the a p projection This opinion is supported by the results of comparative examinations of a few patients with and without laryngeal lesions

In the lateral view xeroradiography gave a better image of the laryngeal cartilages,

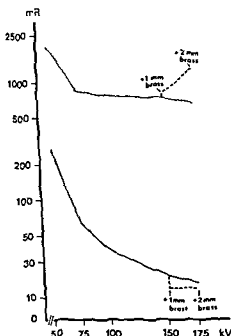


Fig 6 Exposure at 50 to 175 kV in a p conventional radiography (—) and xeroradiography ( ) of the cervical phantom

the soft tissues *anterior to* them, and the epiglottis than conventional radiography at a low tube potential Xeroradiography might thus be of value in cases of laryngeal trauma with possible injury to the cartilages or possible tumour spread outside the laryngeal cavity (Fig 5) For evaluation of the inner surface of the larynx, on the other hand, the systems are equivalent if positive contrast is used, xeroradiography without contrast medium cannot replace the positive contrast examination

The entrance dose in the a p and lateral projections with the recommended techniques, 150 kV + 1 mm extra brass filter, 130 kV and 55 kV, respectively (HEMMINGSSON 1972), was about 30 times higher at xeroradiography than at conventional radiography (Table 2) As the perceptibility of the soft tissue structures in the larynx at xeroradiography was not better than at ordinary radiography in the frontal view even when contrast medium was used, the latter system should still be used for this view Further, in ordinary radiography a high tube potential should be employed, this allows good perception of the contrast-coated surfaces in the laryngel cavity and implies a lower radiation dose to the patient than a lower tube potential This technique should be combined with a lateral view of the soft tissues for evaluation of the laryngeal cartilages and surrounding structures This soft tissue image can be obtained by xeroradiography or by conventional radiography with a low tube potential (55 to 60 kV)

The use of maximum sensitivity of the xeroradiographic system, necessitating negative processing, gives only a small reduction of the radiation dose Furthermore,

negative processing causes distortion of the image through an increase in width of the outlines of the structures. Positive processing is therefore preferable if xeroradiography is chosen.

SUMMARY

Comparison of the visibility and radiation dose at xeroradiography and ordinary conventional radiography have been made in experimental and clinical examinations of the larynx. The investigation indicates that xeroradiography cannot replace positive contrast examination and gives a considerably higher radiation dose than conventional radiography.

ZUSAMMENFASSUNG

Vergleiche der Bildqualität und der Strahlendosis bei Xeroradiographie und gewöhnlicher Radiographie wurden bei experimentellen und klinischen Untersuchungen des Larynx vorgenommen. Die Untersuchungen lassen erkennen, dass Xeroradiographie nicht die Untersuchung mit positivem Kontrastmittel ersetzen kann und eine wesentlich höhere Strahlendosis als gewöhnliche Röntgenuntersuchung gibt.

RÉSUMÉ

Les auteurs ont comparé la qualité des images et la dose de radiation au cours de la *xérographie* et de la radiographie classique du larynx dans des examens expérimentaux et cliniques. Ce travail montre que la xérographie ne peut pas remplacer l'examen avec des moyens de contraste positifs et donne une dose de radiation considérablement plus élevée que la radiographie habituelle.

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ACTIVATION OF THE COMPLEMENT SYSTEM BY WATER-SOLUBLE CONTRAST MEDIA

A preliminary report

M HEIDEMAN, B JACOBSSON and N LINDHOLM

It is well known that water soluble constrast media have side effects Of those generally classified as moderate or severe, hives, erythema, periorbital oedema, cardiovascular shock and bronchospasm are the most common (WITTEN 1975) The cause of these reactions is still obscure, but an accompanying release of histamine has often been reported (LASSER et coll 1971) The reactions have generally been ascribed to antigen-antibody interactions However, cumulative evidence argues strongly against this view, especially the fact that it has not been possible to demonstrate antibodies to the contrast media Severe and sometimes lifethreatening reactions, mostly cardiovascular, occur in a frequency of 1/14 000 to 1/1 100 patients examined

As the complement system includes factors capable of causing release of histamine, as well as a fall in blood pressure and bronchial constriction (BOKISH et coll 1969, GÖTZE & MULLER-EBERHART 1971, BODAMMER & VOGT 1967), it was thought of interest to investigate if any effect of contrast media on the complement system in vitro and in vivo could be demonstrated

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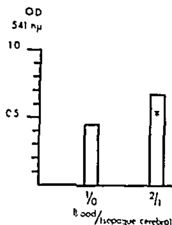


Fig 1

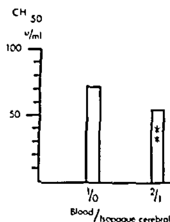


Fig 2

Fig 1 Hemolysis on incubation (60 min at 37 C) of a mixture of blood and contrast medium The optical density (OD) was measured at a wave length of 541 nμ *p < 0.05

Fig 2 Fall in complement activity during incubation (60 min at 37 C) of a mixture of blood and contrast medium **p 0.01

Material, Methods and Results

Blood samples were obtained in connection with routine angiography before, 1 min and 4 min after the injection of Isopaque Cerebral (Nyegaard) as well as later on the same day The complement activity was measured according to the method described by LANGE et coll (1951) In 10 out of 19 patients a transient fall in the complement activity occurred immediately after the injection of the medium

The effect of the contrast medium on the complement activity as well as on hemolysis was investigated in vitro Serum was obtained from whole blood and red blood corpuscles were obtained by centrifugation of the blood and decantation of the plasma Red blood corpuscles and serum were mixed in the same proportion as in the blood and a test sample was withdrawn from the mixture Afterwards samples of the blood were mixed with Isopaque Cerebral in the proportions 1 8, 1 4 and 1 2 These ratios lie within the range that may occur in patients at angiography At higher ratios denaturation of proteins occurred which made analysis of hemolysis or complement activity impossible The presample as well as the mixtures were incubated at 37° for 60 min The optical density was then measured at optimum wave length for hemoglobin (541 nμ) and for the amount of complement according to the CH_{50}-method (MAYER 1967) It was found that the optical density increased with the concentration of Isopaque Cerebral from 0.453 in the presample to 0.679 in the sample containing one part of medium and two parts of blood (Fig 1) The corresponding figures for CH_{50} were 72 CH_{50} units in the presample and 55 CH_{50} units in the blood containing one part of contrast medium and two parts of blood (Fig 2) All these values were corrected for the dilution of blood with the medium The increase in degree of hemolysis as well as the decrease in complement activity was statistically significant

Comments

The findings in vitro as well as those in vivo indicate that contrast media may activate the complement system The only similar findings were reported by LASSER et coll (1974) The ability of contrast media to activate the complement system may help to explain at least some of the side effects observed after the injection of contrast media It has been reported that angiography causes not only the more common side effects but in immunologically labile patients such as those with a *recent transplant*, angiography significantly increases the risk for rejection (HEIDEMAN et coll) Further investigation of the influence of contrast media on the complement system therefore appears urgent

SUMMARY

The effect of contrast medium on the complement system was investigated in vitro as well as in vivo The *medium appeared to activate* the complement system, which might help to explain the side effects of contrast media

ZUSAMMENFASSUNG

Der Effekt von Kontrastmittel auf das Komplementsystem wurde in vitro sowie in vivo untersucht Das Mittel scheint das Komplementsystem zu aktivieren, was die Nebenwirkungen von Kontrastmittel zu erklären helfen mag

RÉSUMÉ

L effet des moyens de contraste sur le système du complément a été etudie in vitro ainsi qu in vivo Le moyen de contraste *paraît activer* le systeme du complement, ce qui pourrait contribuer à expliquer les effets secondaires des moyens de contraste

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SCINTIGRAPHY OF PERICARDIAL EFFUSION

OVE MATTSSON

An isotope method for the diagnosis of pericardial effusion was described by COOK et coll (1975) They combined two isotope labelled compounds in order to obtain a single scintigram displaying heart, liver and lung perfusion simultaneously The patient was given Tc-MMA (1 mCi) for the demonstration of lung perfusion, and immediately after that Tc-HSA (3 mCi) Thus, in a single view heart, liver and lungs were demonstrated and their space relationships could be evaluated

Another method (ÅSARD 1976) involves a combination of emission and transmission images In the former, an intravenously injected isotope (Sodium Pertechnetate, $^{99}Tc^m$) displays the heart cavity and in the transmission image the contours of the heart are obtained The latter is obtained by the use of a homogeneous radiation source in the shape of a flat thin container filled with an isotope added solution The thickness of the cardiac wall may thus be evaluated In the present method for demonstration of pericardial effusion only one compound is used, the procedure is not more time consuming than conventional liver scintigraphy In principle, the present method is based upon hepatic scintigraphy The heart and lung perfusion is displayed during the initial period following the injection and this information is combined with the image of the liver displayed in a subsequent phase The compound injected always passes through the heart and lungs before it is accumulated in the liver and spleen The different phases are not distinctly separated, a gradual change of the distribution of the isotope occurs Although, a summation image as produced

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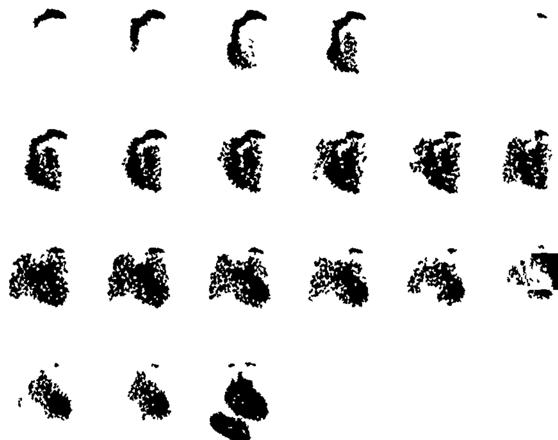


Fig 1 Relatively narrow space between heart and liver Absence of pericardial effusion confirmed clinically

in a conventional scintillation camera may be useful, it is an advantage to employ a scintiphoto system enabling a rapid sequence display Such systems are today in common use and have contributed to an improvement of the hepatic scintigraphy, e g by making possible 'dynamic scintigraphy' (STADALNIK et coll 1975)

The practical details in the present heart–lung–liver examination may be briefly described as follows Technetium sulphide colloid ($^{99}Tc^{m}$), being the ordinary compound for hepatic scintigraphy, is given intravenously During the injection a rapid series of scintiphoto images is recorded, each with an exposure of 2 s and the shortest possible intervals A summation image is finally made based upon 500 000 counts, the latter often giving the most valuable information The camera is centered on the interspace between the heart and the liver Afterwards, if desirable, conventional hepatic scintigraphy with various projections may be performed The normal distance between the heart, the lungs and the liver is demonstrated in Fig 1

If a pericardial effusion exists, these distances are increased (Figs 2, 3) All cases were clinically confirmed regarding absence or presence of pericardial fluid The

Fig. 2 Increased space between the heart and the lungs–liver Pericarditis confirmed clinically Dynamic rapid series and summation image



Fig. 3 Pericardial effusion demonstrated by conventional scintillation camera Summation image only

method is simple, involving no additional manipulation of the patient compared with the conventional hepatic scintigraphy, to which it might be considered as a complement The examination time is a minimum and gives no delay as it is included in the ordinary scintigraphic time, occupying its initial period The images, obtained with a dose as low as 2 mCi—normal for liver imaging—are of a satisfactory quality It must be pointed out that other space-occupying lesions between heart and liver, as for instance subphrenic abscesses, may be detected with this method

SUMMARY

A simple and rapid scintigraphic method for the demonstration of pericardial effusion is described It is complementary to hepatic scintigraphy, makes use of one isotope only and requires no extra time or patient manipulation

ZUSAMMENFASSUNG

Eine einfache und rasche Szintigraphiemethode zur Darstellung eines Pericardergusses wird beschrieben Sie ist eine Zusatzuntersuchung zur Leberszintigraphie, nur ein Isotop wird verwendent und keine verlangerte Untersuchungszeit oder Manipulationen des Patienten sind notwendig

RÉSUMÉ

Description d'une méthode scintigraphique simple et rapide pour la mise en évidence des épanchements péricardiques Elle est complémentaire de la scintigraphie hépatique n'utilise qu'un seul isotope et ne nécessite pas une prolongation de l'examen ni d'autres manipulations du malade

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ADVERSE EFFECTS OF STATIONARY GRIDS

SVEN REICHMANN and KARL-GUSTAV STRID

Stationary grids are commonly used today in angiography and pulmonary radiography, although it has been known for at least 20 years that this technique substantially impairs image quality MATTSSON (1955) gave clear evidence of this impairment, and later (1956) he illustrated its harmful effects in pulmonary radiography Still, stationary grids are incorporated even into modern diagnostic equipment, the reason appears to be that radiologists in general and probably also manufacturers do not realise to what extent image quality is lowered by the grid Often stationary grids with a strip density value of 40 cm^{-1} are accepted because 'the grid lines are so thin as to be practically invisible' The following simple series of experiments were performed to demonstrate that such an invisibility is no guarantee against impairment of image quality

Experiments

Influence of a grid on image quality The first test was intended to analyse how different signals are affected A Lysholm grid with strip density 40 cm^{-1} and ratio 12 was used and the grid was exposed on industrial non-screen film No object was present in the beam except the grid, thus, a high quality image of the grid was obtained

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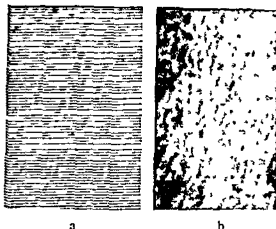


Fig 1 Macerated femur in water By means of printing stationary grid strips have been introduced The strip density is a) 40 cm^{-1} and b) 80 cm^{-1} The information content in (b) is higher than in (a) being practically the same in (b) as in the original image without visible grid strips

This image was photographed on a hard-working 35 mm film, thus the original negative image was converted into a positive one At the sites of the interspaces of the grid, this second image was translucent to light The image was placed in a photographic enlarger in order to create a projected image of the grid By varying the degree of magnification, different grid strip densities could be obtained in the projected image In the projection plane, different images were contact-printed onto Kodak *RP/SU* subtraction film, giving a gamma value of *1 0* The printing was performed by the light from the enlarger The resulting prints thus displayed the same contrast as the original films and also contained the grid image By comparison of the prints with the originals it was possible to conclude how the grid strips *interacted with different elements in the original image*

Three films of a macerated femur in water were printed They differed from each other in contrast and background mottle Strip densities of 40, 60, 80, 120 and 160 cm^{-1} were simulated

The original strip density of 40 cm^{-1} was found to lower the image quality (Fig 1), weak signals were affected more than strong ones The strips impaired the image quality in the same manner as any type of mottle One of the original images contained marked background mottle, which mainly derived from the inhomogeneous crystal texture of the intensifying screens (cf REICHMANN & HELANDER 1974) Even this background mottle was made largely invisible by the grid When the strip density was increased, the original image quality was gradually restored At 80 cm^{-1} practically no adverse effects could be demonstrated The prints then displayed all the information—including background mottle—of the original images

In the experiment described the grid strips were much more clearly visible than they usually are in clinical radiography In the following experiments two factors reducing grid strip visibility were analysed, viz secondary radiation and the scattering of light

Effect of secondary radiation To demonstrate the influence of secondary radiation a cylindrical plastic basin (diameter 25 cm) filled with water was exposed A Lung



Fig 2 Film of a stationary grid (40 cm^{-1}) obtained at 120 kV potential A water basin was placed close to the tube side of the grid a) The exposure of the film was caused by secondary radiation only since the primary radiation was screened off by a small lead plate on the tube side of the basin No grid strips are visible, the radiation having passed obliquely through the lead strips Screen mottle is clearly visible b) Primary as well as secondary radiation formed the image The secondary radiation makes the grid strips disappear and enhances the visibility of the screen mottle, it appears in every point of the image

Photo Stand type MAS (Siemens Elema, Solna, Sweden) with a stationary grid (strip density 40 cm^{-1}, ratio 12) and FFD 150 cm was used First the basin was placed close to the tube The radiation reaching the recording medium (different combinations of film and intensifying screens) behind the stationary grid then contained insignificant secondary radiation This was evident from the films, since a piece of lead (thickness 3 mm) had been attached on the tube side of the basin and no blackening occurred in the corresponding film area The films were exposed at tube potentials of 70 and 120 kV The same procedure was then repeated with the water basin being placed next to the stationary grid In this case large amounts of secondary radiation reached the recording medium, particularly at 120 kV In the area screened from primary radiation by the lead piece, background blackening appeared (Fig 2), no grid strips were visible, only the background mottle caused by the screens The additional blackening induced by secondary radiation reaching the recording medium reduced the grid strip visibility in the area exposed to the primary radiation Thus, secondary radiation reached the recording medium so that the grid strips were not depicted by this radiation

Effect of light scattering Light scattering may occur within the crystal layer of an intensifying screen Another mechanism is 'cross-over exposure', implying that light from one intensifying screen passes through the adjacent film emulsion layer and through the film base as well, giving rise to blackening of the opposite emulsion layer The image thus created will be unsharp due to diffusion of light (Fig 3) When calcium tungstate screens are used in conjunction with a moving grid, 25 to 30 per cent of the blackening of a double emulsion film derives from cross over

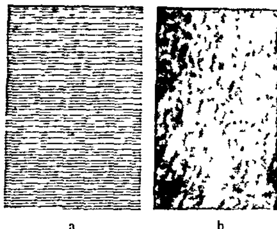


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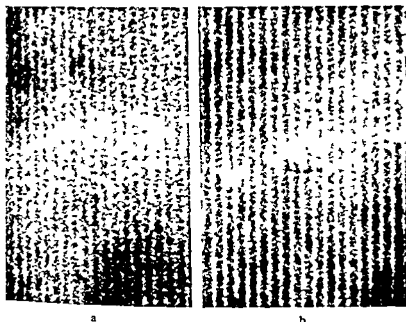
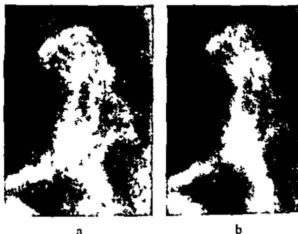


Fig 4 Magnified (× 12) detail of chest film of the same subject (130 kV strip density 40 cm⁻¹) a) Exposed to conventional density b) underexposed The bright lines corresponding to the lead strips of the grid stand out more clearly in (b) The density variations of the image appear in the bright lines as well as in the dark ones the effect being more marked in (a) due to greater influence of scattered light

the adverse influence of the grid on the desired signals Instead they contribute to impair the whole image—signals as well as the appearance of the grid Low visibility of the grid strips thus implies extra low image quality A way of testing the screening capacity of a grid is to observe the strip visibility A suitable grid should give rise to distinct lines due to satisfactory secondary screening Moving grids could be tested by the same procedure if they are kept stationary during the test exposure

Significant amounts of secondary radiation may pass obliquely through the thin lead strips of the stationary grids usually employed in angiography and pulmonary radiography Such grid insufficiency has been recognised previously (OOSTERKAMP 1946) Secondary radiation not only impairs the signals and reduces the visibility of the grid strips it also affects the background quantum mottle This mottle is caused by fluctuations in the distribution of photons, giving the image a coarsely granular background In the photographic experiment with different grids, the grid mottle was found to lower the visibility of quantum and screen mottle The imaging of quantum mottle is impaired by the same mechanism as is that of the desired signals the mottle cannot appear in the image behind the lead strips of the grid In this way the grid mottle might seem to be the only mottle of importance However, with significant amounts of secondary radiation reaching the recording medium quantum



intensifying screen a) The emulsion next to the screen was developed b) Only the opposite emulsion was developed The radiation exposure was increased by a factor of 3 when the image in (b) was recorded The unsharpness in (b) demonstrates the effect of the cross over exposure

exposure (SELIN & REICHMANN, a) When a stationary grid is used, it might be expected that light will spread into the bright lines of the image created by the lead strips of the grid This was evident by mere inspection of routine films through a magnifying glass (12 diopters) Thus, 20 pulmonary images (tube potential 130 kV, calcium tungstate screens, 40 cm^{-1} grid) were inspected The signals of the images were constantly found to appear not only in the dark lines of the image, but in the bright ones as well (Fig 4) Since the signals cannot pass through the lead strips of the grid, this must be evidence of light scattering leading to increased blackening of the bright grid lines of the image This, in turn, corresponds to a reduction of grid strip visibility

Discussion

A stationary grid gives rise to background density variations in the image, affecting the visibility of image detail in largely the same way as statistical fluctuations, commonly referred to as mottle The 'grid mottle is so predominant that behind the lead strips no signals occur within the radiation relief The signals are thus completely extinguished by the grid mottle in many points of the image Strong and weak signals are not affected to the same degree by the grid mottle Instead, the weak signals are especially vulnerable, so that they tend to disappear completely from the final image recorded on the film The mottle effect created by a stationary grid seems to be related to strip density The finest grids obtainable today have strip density values of about 40 cm^{-1} The grid mottle produced by such a grid is considerable in relation to the imaging of spongious bone substance, which represents a set of diagnostic signals of high spatial frequency It appears that a more acceptable level of grid mottle would be achieved if a strip density value of 80 cm^{-1} could be obtained

Two factors have been found to reduce the visibility of the grid mottle in the final image secondary radiation and unsharpness due to light scattering Both may be regarded as undesired components in the imaging process They do not counteract

blackening that contains information need not be placed at extremely high density levels. An image appearing properly exposed is also properly exposed.

The use of a stationary grid in abdominal angiography and pulmonary radiography interferes with the reproduction of weak signals in several ways, via grid mottle, quantum mottle, secondary radiation, and unfavourable density levels. The first and last of these factors are readily eliminated by grid motion. They are both considerable and tend to cooperate with the other noise factors, making the signal-to-noise ratio unnecessarily bad. Since both kinds of examinations mentioned yield the diagnostically important information mostly by means of weak signals, it must be stated that stationary grids should be abandoned as often as is technically possible. Furthermore, moving grids need not have the thin strips and consequently the low lead content of the stationary grids with high values of the strip density. Increased lead content will render better secondary screening (BONENKAMP & HONDIUS BOLDINGH 1959). This means further improvement of image quality. Grid motion in angiography requires synchronisation between grid movement and exposure intervals. This was accomplished by MATTSSON (1955). BOOKSTEIN & VOEGELI (1971) describe a grid rotating in its own plane around its centre point. Under such conditions no synchronisation need at all be performed.

SUMMARY

By means of simple tests the mechanisms of image impairment due to stationary grids were demonstrated. [illegible]

[illegible] are perceptible.

ZUSAMMENFASSUNG

Mittels eines einfachen Tests wurde der Mechanismus der Bildverschlechterung durch stationäre *Gitter demonstriert*. Verschiedene beitragende Faktoren wurden gefunden. Die Tatsache, dass *die Gitterstreifen auf* einem *Film* nicht deutlich sichtbar sind, deutet nicht darauf hin, dass die Bildqualität durch das Gitter nicht verschlechtert wird. *Zu einem gewissen Grad* demonstriert das, dass die Bildqualität so gering ist, dass selbst die Gitterlinien nicht erkennbar sind.

RESUMÉ

Les auteurs montrent au moyen de tests simples les mécanismes de la détérioration de l'image due aux *grilles fixes*. *Ils ont constaté* que plusieurs facteurs y contribuent. Le fait que les lames de la *grille ne sont pas nettement visibles sur le film* ne prouve pas que la qualité de l'image n'a pas été diminuée *par la grille*. Il *montre* dans une certaine mesure, que la qualité de l'image est si mauvaise que *même les lames de la grille* ne sont pas perceptibles.



Fig 5 Detail from chest film of the same subject (130 kV, strip density 40 cm⁻¹) a) Exposed to conventional density, b) underexposed with contrast and density adjusted in printing to the same levels as in (a) The underexposed image displays greater richness in detail

mottle—and screen mottle—can appear in every point of the image (Fig 2) For this reason, a disturbing quantum mottle tends to appear together with the grid mottle when secondary screening is insufficient Thus, the grid mottle primarily affects the signals and the quantum mottle in the same way, the secondary radiation passing through the grid impairs the signals and enhances the quantum mottle

The dark lines in a film obtained with a stationary grid must have a blackening value greater than the apparent density of the image in order to compensate for the light leaking through the bright lines This may further impair image quality Every film has an optimum density value where its capacity is at its maximum for detecting weak signals (DE BELDER & BOLLEN 1971, SELIN & REICHMANN a) This density value usually amounts to 1 0 to 1 4 for black-and-white roentgen films (SELIN & REICHMANN, b) When the density is further increased, the film gradually loses its capacity to record weak signals In the central area of a properly exposed chest film the overall density is usually about 1 6, which means that the density of the dark lines is even higher In many types of roentgen film a significant reduction of the recording capacity must then be expected (SELIN & REICHMANN, a, b) This circumstance explains a phenomenon often encountered (Fig 5) If a chest film is underexposed, so that the lateral parts of the image display insufficient blackening, many pulmonary vessels are visible in the central area, not appearing in a properly exposed image A distension of the pulmonary vessels may even be suggested in the underexposed film In this image the dark lines are properly exposed, the presence of the bright lines makes it look underexposed With a moving grid, no bright lines will occur and the

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HYDRO- AND HEMODYNAMIC EFFECTS OF CATHETERIZATION OF VESSELS

II Model experiments comparing circular and annular lumen area reduction

L BJORNO and H PETTERSSON

Stenosis of an artery has a complicated influence upon the flow of blood through and beyond the narrowed segment The hydro- and hemodynamic effects of stenoses in arteries have been thoroughly investigated both clinically and in animal experiments and by means of theoretical and mechanical models (BYAR et coll 1965, EKLÖF & SCHWARTZ 1970, FIDDIAN et coll 1964, HAMILTON et coll 1963, KINDT & YOUMANS 1969, MANN 1938, MAY et coll 1963 a, b, WEALE 1968, WEISSENHOFFER & SCHENK 1974)

In principle, an 'ideal' stenosis is a circular constriction of a vessel (MAY et coll 1963 a) A reduction of the lumen of a vessel may also arise from an introduced catheter, which leaves an annular opening for the blood flow between the outer wall of the catheter and the inner wall of the artery Only a few reports on hydro- and hemodynamic effects of this annular lumen area reduction of vessels have appeared (BERÁNEK 1971, CROWE & KROVETZ 1970, KANAI et coll 1970)

Whether the experiences of the flow through stenoses may be directly applied to

From the De[illegible]
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Malmö, Swede[illegible]

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inner diameter of 10.0 mm. The branch vessel was interchangeable, and for some series of experiments it consisted of a rigid-walled perspex tube with an inner diameter of 4.1 mm, while for other series of experiments it was replaced by an elastic-walled latex tube, having an inner diameter of 4 mm and an outer diameter of 5.5 mm. The latex material had a density of $\varrho = 880$ kg/m^3 and a bulk modulus of 2.1×10^9 Pa. This should be compared to the properties of the arterial wall: $\varrho = 900$–$1\ 100$ kg/m^3 and bulk modulus 2.2–2.3×10^9 Pa (McDonald 1974).

The pressure measurements were carried out by means of hypodermic needles, connected by polyethylene catheters to pressure transducers (Siemens-Elema EMT 34, 0 to 300 mmHg). Both the stagnation pressure in the vessel axis and the static (lateral) pressure were measured at the positions denoted X_1 and X_2 (Figure) in order to yield the dynamic pressure part, which is the difference between the stagnation and the static pressures. The dynamic pressure originates from the local particle velocity of the fluid flow. The pressure measurements were carried out with an accuracy of ± 2 per cent of full scale display.

The measurements of the volumetric flow rate through the branch vessel were performed by means of a modified flowmeter, EMT 434 (Siemens-Elema). The flow rate measurements in the interval 40 to 1 500 ml/min were carried out with an accuracy of ± 2 per cent of full scale display.

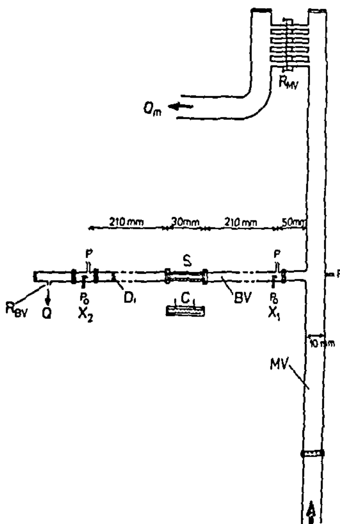
The pressure and volumetric flow rate were recorded on paper tape by means of a recording device (Siemens-Elema Mingograf 800).

The volumetric flow rates through the main vessel and the branch vessel were adjusted by means of appropriate peripheral resistances (Figure, for details, see Part I).

The stenoses and catheter pieces were centrally positioned between the two positions X_1 and X_2 (Figure). The stenoses were perspex cylinders, having coaxially drilled lumina of various diameters. The outer diameter of the cylinder was identical to that of the branch vessel and the joints between them were made watertight by means of soft plastic tubes fitted over the joints. The catheter pieces of various diameters were centrally positioned in the lumen of the branch vessel and were held in place by means of two needles of 0.4 mm outer diameter. These needles were stuck through the wall of the branch vessel into the catheter piece (Figure). The lumen of the catheter pieces was plugged at both ends.

Some of the factors influencing the flow through and the pressure loss across a stenosis are: the diameter of the vessel and the diameter of the stenosis, the length of the stenosis, the proximal pressure and the peripheral resistance of the stenosed vessel, and the viscosity of the liquid flowing through the stenosis. Of minor but for some flow rates of increasing importance are the inlet and outlet configurations, surface roughness etc., of the stenosis.

The length of the stenosis has a disproportionately small effect on the hemodynamics (Byar et coll. 1965, Fiddian et coll. 1964, Kindt & Youmans 1969). In all the experiments the length of the stenoses and of the catheter pieces were 30 mm.



The experimental set up, illustrating the main vessel (MV) and the branch vessel (BV) together with the lumen area reductions of the branch bessel Measuring sites in the branch vessel are marked X_1 and X_2 → Direction of the fluid flow S—Interposed circular constriction (stenosis) in the branch vessel C—Annular obstruction (catheter piece), to be interchanged with the circular constriction in the branch vessel R_{MV}—Interchangeable peripheral resistance of the main vessel R_{BV}—Interchangeable peripheral resistance of the branch vessel D_i—Inner diameter of the branch vessel P—Needles for static pressure measurements P_0—Needles for stagnation pressure measurements Q—Site for measurement of the volumetric flow rate through the branch vessel Q_m—Site for measurement of the volumetric flow rate through the distal part of the main vessel

the flow around catheters in vessels is not known Thus, it seemed of interest to attempt to elucidate the hydrodynamic effects of circular and annular obstruction of the flow in rigid- and elastic-walled vessels using the mechanical model described in Part I (BJORNO & PETTERSSON 1976)

Material and Methods

The mechanical model consists of three main parts (1) an apparatus producing controllable flow and pressure variations, (2) a model of the vessels to be stenosed or catheterized, (3) a recording device for pressure and flow volume readings The model of the main vessel (MV) and branch vessel (BV) to be stenosed or catheterized appears in the Figure, which illustrates the dimensions of the flow model, together with the positions for measurement of stagnation and static pressure

In all experiments, the main vessel was a rigid-walled perspex tube, having an

inner diameter of 10 0 mm The branch vessel was interchangeable, and for some series of experiments it consisted of a rigid-walled perspex tube with an inner diameter of 4 1 mm, while for other series of experiments it was replaced by an elastic-walled latex tube, having an inner diameter of 4 mm and an outer diameter of 5 5 mm The latex material had a density of $\varrho = 880$ kg/m³ and a bulk modulus of $2\,1 \times 10^9$ Pa This should be compared to the properties of the arterial wall $\varrho = 900$–1 100 kg/m³ and bulk modulus 2 2–2 3 × 10⁹ Pa (McDonald 1974)

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Table 1

Lumen diameters of stenoses (d_s) and outer diameter of catheter pieces (d_c) used in the experiments and their corresponding lumen area reduction (D_s and D_c) in per cent of the original cross sectional area of the vessel

Rigid walled vessel (inner diameter 4.1 mm)				Elastic walled vessel (inner diameter 4 mm)			
Stenosis		Catheter		Stenosis		Catheter	
d_s (mm)	D_s (%)	d_c (mm)	D_c (%)	d_s (mm)	D_s (%)	d_c (mm)	D_c (%)
3.9	10	1.1	7	3.9	5	1.1	8
3.6	23	2.0	24	3.6	19	2.0	25
3.0	46	2.8	47	3.0	44	2.8	49
2.6	60	3.2	61	2.6	58	3.2	64
2.1	74	3.5	73	2.1	72	3.5	77

A change in the viscosity of the liquid will influence both the drag and the character of the flow, but in opposite directions, i.e. a change to higher viscosity will make the drag greater, but at the same time stabilize the flow. To avoid an interplay of these opposite effects, the same liquid at constant temperature and thus with constant viscosity has been used in all experiments. The liquid used was tap water, at 30°C, having a kinematic viscosity of $\nu = 0.85 \times 10^{-6}$ m²/s, measured by means of an Ostwald viscosimeter.

The static and stagnation pressure in the main vessel at the inlet to the branch vessel was kept constant at $p_m = 12 \times 10^3$ Pa, i.e., 90 mmHg (1 mmHg = 133.3 Pa). The volumetric flow rate in the main vessel distal to the branch vessel varied between 2 000 and 2 200 ml/min in all the experiments. This flow rate was measured by means of stopwatch and measuring glass.

The experiments were performed at steady and pulsatile flow both in the rigid and elastic-walled branch vessel.

In most series, the proximal and distal ends of the stenoses and the catheter pieces were cut at right angles. In order to investigate the influence of the geometrical shape of the stenoses and of the catheter pieces, a test series was performed, using streamlined stenoses and catheter pieces.

Experimental results and Discussion

The results of the experiments and a discussion of their relation to a simple theoretical analysis may appropriately be divided into four sections, namely: (1) The volumetric mean velocity at steady flow in vessels without and with lumen area reduction, (2) loss in static pressure at steady flow in vessels, (a) without, and (b) with lumen area reduction, (3) loss in pressure at pulsatile flow in vessels without and with

Table 2

Volumetric mean velocity u_m (m/s) in steady flow through stenoses in rigid walled vessel

	Q_s = 1 060 ml/min		Q_s = 500 ml/min		Q_s = 250 ml/min		Q_s = 117 ml/min	
	$u_{m\,a)}$	$u_{m\,b)}$	$u_{m\,a)}$	$u_{m\,b)}$	$u_{m\,a)}$	$u_{m(b)}$	$u_{m\,a)}$	$u_{m(b)}$
F(D = 0%)	1 34	1 32	0 63	0 69	0 32	n m	0 15	n m
D_s = 10%	1 34	1 32	0 63	0 69	0 32	n m	0 15	n m
D_s = 23%	1 34	1 32	0 63	0 69	0 32	n m	0 15	n m
D_s = 46%	1.24	1.23	0 63	0 69	0 32	n m	0 15	n m
D_s = 74%	0 93	0 98	0 55	0 57	0 30	0 26	0 15	n m

Table 3

Volumetric mean velocity u_m (m/s) in steady flow around catheter pieces in rigid walled vessel

	Q_s = 1 060 ml/min		Q_s = 500 ml/min		Q_s = 250 ml/min		Q_s = 117 ml/min	
	$u_{m\,a)}$	$u_{m\,b)}$	$u_{m\,a)}$	$u_{m\,b)}$	$u_{m\,a)}$	$u_{m\,b)}$	$u_{m\,a)}$	$u_{m\,b)}$
F(D 0%)	1 34	1 32	0 63	0 69	0 32	n m	0 15	n m.
D_c = 7%	1 34	1 32	0 63	0 69	0 32	n m	0 15	n m
D_c = 24%	1 23	1 23	0 63	0 69	0 32	n m	0 15	n m
D_c = 47%	1 07	1 17	0 60	0 69	0 30	0 26	0 15	n m
D_c = 73%	0 48	0 56	0 38	0 40	0 25	0 26	0 14	n m

lumen area reduction, (4) the volumetric mean velocity at pulsatile flow in vessels without and with lumen area reduction

Volumetric mean velocity at steady flow in vessels without and with lumen area reduction Table 1 gives the lumen diameters of the stenoses (d_s) and the outer diameters of the catheter pieces (d_c) together with the corresponding lumen area reduction of the branch vessel (D_s and D_c)

This reduction of the lumen area, when produced by a stenosis, is defined by the equation

$$D_s = \frac{A_w - A_s}{A_w}\ 100\ (\%) \tag{1}$$

with A_w being the lumen area of the branch vessel and A_s the lumen area of the stenosis For catheter pieces the lumen area reduction is defined by the equation

$$D_c = \frac{A_c}{A_w}\ 100\ (\%) \tag{2}$$

where A_c is the cross sectional area of the catheter piece

Table 4

Volumetric mean velocity u_m (m/s) in steady flow through stenoses in elastic walled vessel

	Q_0 = 1 040 ml/min		Q_0 = 500 ml/min		Q_0 = 255 ml/min		Q_0 = 120 ml/min	
	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$
F (D = 0%)	1 39	1 41	0 66	0 69	0 34	n m	0 16	n m
D_s = 5%	1 39	1 41	0 66	0 69	0 34	n m	0 16	n m
D_s = 19%	1 36	1 41	0 66	0 69	0 34	n m	0 16	n m
D_s = 44%	1 31	1 35	0 66	0 69	0 34	n m	0 16	n m
D_s = 72%	0 93	1 00	0 60	0 69	0 33	0 26	0 16	n m

Table 5

Volumetric mean velocity u_m (m/s) in steady flow around catheter pieces in elastic-walled vessel

	Q_0 1 040 ml/min		Q_0 500 ml/min		Q_0 255 ml/min		Q_0 120 ml/min	
	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$	$u_{m(a)}$	$u_{m(b)}$
F (D = 0%)	1 39	1 41	0 66	0 69	0 34	n m	0 16	n m
D_c 8%	1 39	1 41	0 66	0 69	0 34	n m	0 16	n m
D_c 25%	1 28	1 34	0 66	0 69	0 34	n m	0 16	n m
D_c 49%	1 12	1 18	0 63	0 69	0 33	0 26	0 16	n m
D_c = 77%	0 52	0 56	0 43	0 56	0 28	0 26	0 16	n m

A comparison between the volumetric mean velocity of the flow through the branch vessel without (F) and with various degrees of lumen area reduction (D_s and D_c) appears in Tables 2 to 5

Q_0 in ml/min refers to the volumetric flow rate for steady flow through the branch vessel without any reduction of the lumen area

The values $u_{m(a)}$ in Tables 2 to 5 designate the volumetric mean velocities of the flow in the branch vessel without (F) and with various degrees of lumen area reduction (D_s and D_c) On the basis of the measured volumetric flow rate Q (ml/min) through the branch vessel $u_{m(a)}$ is calculated by means of the equation

$$u_{m(a)} = \frac{Q}{60} \frac{4}{\pi D_i^2} \quad (m/s) \tag{3}$$

where D_i is the inner diameter of the branch vessel

The volumetric mean velocities $u_{m(b)}$ in Tables 2 to 5 are based upon the dynamic pressure on the vessel axis at position X_1 in the Figure Thus, the measurements at position X_1 of the stagnation pressure on the vessel axis and the static (lateral) pressure give the maximum velocity U_{max} in the vessel, expressed by

$$U_{max} = \sqrt{(p_0 - p) \cdot \frac{2}{\varrho}} \quad (m/s) \tag{4}$$

where p_0 and p (Pa) are the stagnation and static pressure, respectively $\varrho = 966\ kg/m^3$ is the density of water at 30°C

The maximum velocity of the flow, which for both laminar and turbulent velocity profiles will be found on the vessel axis, may be related to the volumetric mean velocity $u_{m(b)}$ by the equation

$$u_{m(b)} = \frac{U_{max}}{2} \quad (m/s) \tag{5}$$

for laminar flow, and

$$u_{m(b)} = \frac{U_{max}}{1 + 1\ 441 \sqrt{\lambda}} \quad (m/s) \tag{6}$$

for turbulent flow, where λ is a dimensionless friction factor related to the Reynold's number (Re) by the formula

$$\frac{1}{\sqrt{\lambda}} = 0\ 87\ \ln(Re \sqrt{\lambda}) - 0\ 8 \tag{7}$$

Reynold's number of the flow is calculated from the equation

$$Re = \frac{u_{m(a)}\ D_i}{\nu} \tag{8}$$

where ν is the kinematic viscosity (m^2/s)

Equations 4, 5, and 8 are well known from the fluid mechanics literature and equations 6 and 7 are for instance given by BJØRNO (1972)

The symbol n m (= not measurable) in Tables 2 to 5 denotes that the dynamic pressure was less than 1 mmHg (133 3 Pa), and thus, within the inaccuracy of the pressure measurements

The volumetric mean velocity values in Tables 2 to 5 demonstrate the applicability of both methods for calculation of the flow velocities The agreement stated in the tables further reveals that simple fluid mechanical calculations may be performed with a reasonable accuracy for the flow outside the lumen area reduction

The same agreement between $u_{m(a)}$ and $u_{m(b)}$, calculated on the basis of the dynamic pressure at position X_2 (Figure), was found for all flows in the column $Q_0 = 1\ 050$ ml/min However, for some flows in the column $Q_0 = 500$ and $Q_0 = 250$ the agreement was obtained after having switched over from a laminar calculation at position X_1 to a turbulent calculation at *position* X_2 This is explained by a transition in the branch vessel from laminar to turbulent flow, caused by the lumen area reduction

MAY et coll (1963 b) reported that it is necessary to have a marked stenosis of an artery before the distal blood flow and pressure are perceptibly reduced When this

Table 6

Loss in static pressure at steady flow between two positions with a mutual distance of 45 cm in vessels without lumen area reduction

Rigid walled vessel			Elastic-walled vessel		
Q_0 (ml/min)	Δp_{meas} (Pa)	Δp_{calc} (Pa)	Δp_{meas} (Pa)	Δp_{calc} (Pa)	Q_0 (ml/min)
1 060	1 070	1 150	3 600	3 600	1 040
500	915	890	935	950	500
205	270	220	270	250	255
117	133	102	n m	115	120

'critical stenosis' is reached, further small increases in the degree of the stenosis cause significant reduction in flow and pressure. Due to the fact that $u_{m(a)}$ (m/s) represents the volumetric flow rate Q (ml/min) obtained from eq. 3, Tables 2 to 5 show not only the existence of such a critical stenosis but also a corresponding critical annular lumen area reduction, caused by the catheter pieces. It is also obvious from the tables, that the critical D-values caused by the stenoses are higher than those caused by catheter pieces. The very stable laminar flow in the test series of $Q_0 = 117$ ml/min displaces the critical annular lumen area reduction to D-values above the highest investigated.

From the tables it is also evident that a tendency exists to displace the critical annular lumen area reduction to higher D-values in elastic-walled vessels, compared with rigid-walled vessels. This stabilizing influence of the flow, arising from the elastic vessel, may be due to a small increase in the diameter of the vessel around the catheter piece due to the flow condition at the inlet and outlet from the annular lumen.

Loss in static pressure at steady flow in vessels without lumen area reduction. The loss Δp in static pressure at steady laminar or turbulent flow in a vessel of constant cross-sectional area may be determined by means of the equation

$$\Delta p = \lambda \frac{L}{D_i} \varrho \frac{u^2_{m(a)}}{2} \quad \text{(Pa)} \tag{9}$$

(BJØRNØ 1972), where λ is the dimensionless friction factor given for laminar flow by

$$\lambda = \frac{64}{Re} \tag{10}$$

For turbulent flow, in smooth vessels, λ may be found from eq. 7, while the Reynold's number is given by eq. 8. L is an axial length and D_i is the inner diameter of the vessel.

Using eq. 9, the loss in static pressure Δp between the positions X_1 and X_2 may be

Table 7

Dimensionless ratio between the static pressure loss Δp_c across stenosis or catheter piece in the rigid-walled vessel, and the static pressure loss Δp along the same part of the vessel, after removal of the lumen area reduction

D_s	Q_0			D_c	Q_0		
	Stenosis				Catheter piece		
	1 060	500	250		1 060	500	250
$F(D_s=0\%)$	1	1	1	$F(D_c=0\%)$	1	1	1
$D_s=10\%$	1	1	—	$D_c=7\%$	1	1	—
$D_s=23\%$	1 07	1	—	$D_c=24\%$	1 41	1 15	—
$D_s=46\%$	1.39	1 15	—	$D_c=47\%$	1 77	2.00	3 44
$D_s=74\%$	2 44	3 41	4 45	$D_c=73\%$	3 15	8 30	15 70

calculated for vessels without lumen area reduction These values may be compared with the measured static pressure losses between the same positions The results of this comparison have been compiled in Table 6, where Δp_{meas} and Δp_{calc} denote measured and calculated losses in static pressure between the positions X_1 and X_2

The applicability of the simple fluid mechanical formula (eq 9) for calculation of pressure loss in rigid- and elastic walled vessels appears in Table 6 The preservation of the characteristic velocity profile, i e , the laminar or the turbulent velocity profile, from position X_1 to position X_2 is a fundamental condition for the applicability of eq 9 The stability of the velocity profile was controlled by measuring the dynamic pressure by traversing the flow cross section at both position X_1 and X_2 By measuring the static pressure at the intervals of 5 cm between positions X_1 and X_2 it was found that the pressure loss between these locations was linear

The somewhat higher loss found for the turbulent flow, i e $Q_0=1\,060$ ml/min and $Q_0=500$ ml/min, in the elastic-walled vessel compared with the rigid-walled vessel is due to the reduced diameter (4 mm) of the elastic-walled vessel together with the character, i e roughness of the inner wall of this vessel

Loss in static pressure at steady flow in vessels with lumen area reduction MAY et coll (1963 b) demonstrated that the static pressure loss of flow through a stenosis is the sum of three contributions (1) The pressure loss at the inlet, where pressure is transformed into velocity in a process in which a minor turbulence generation may take place, (2) the pressure loss during the flow axially along the stenosis, an increase in turbulence takes place in this flow, but the pressure loss is frequently of minor importance compared with the inlet and outlet losses, and (3) the pressure loss at the outlet from the stenosis, where velocity is transformed into pressure, the flow distal to the stenosis may be strongly turbulent

Sources of static pressure loss like the ones found for the flow through stenoses, but leading to more severe losses, may be found for the flow around catheter pieces

Table 8

Dimensionless ratio between the static pressure loss Δp_c across stensosis or catheter piece in the elastic walled vessel, and the static pressure loss Δp along the same part of the vessel, after removal of the lumen area reduction

D_s	Q_0			D_c	Q_0		
	Stenosis				Catheter piece		
	1 040	500	255		1 040	500	255
$F(D_s = 0\%)$	1	1	1	$F(D_c = 0\%)$	1	1	1
$D_s = 5\%$	1	—	—	$D_c = 8\%$	—	—	—
$D_s = 19\%$	1 11	—	—	D_c 25%	1 42	1 14	—
$D_s = 44\%$	1 33	1 42	—	$D_c = 49\%$	1 78	2 13	3 50
$D_s = 72\%$	2 11	3 40	3 96	$D_c = 77\%$	3 00	8 00	13 70

Tables 7 and 8 give the quotient values $\Delta p_c/\Delta p$ of the static pressure loss, where Δp_c denotes the static pressure loss across the lumen area reduction, and Δp the static pressure loss along the same part of the vessel, without introduced stenosis or catheter piece The Δp_c values were calculated from measurements at positions 10 mm proximal and 10 mm distal to the stenosis or catheter piece, and the Δp values were calculated from Table 6 for the same measurement positions As Δp_{meas} for Q_0 117 ml/min (Table 6) is only 133 Pa (1 mmHg), and thus within the inaccuracy of the measurements, only the value for flow volume rates Q_0 250 ml/min have been included in Tables 7 and 8

The tables show how the relative influence of the lumen area reduction increases for a decrease in volumetric flow rate This is due to the fact that at low volumetric flow rates the lumen area reduction leads to transition from laminar to turbulent flow in the branch vessel This transition leads to higher pressure losses, compared with the lower losses at laminar flow in the vessel without lumen area reduction It also means that the turbulence causing influence of the elastic vessel wall seems to be a reality

Both tables reveal the existence of much stronger pressure losses by the catheter piece than by the stenosis, due to the position of the catheter in that (axial) part of the flow, where the particle velocity has its maximum in both laminar and turbulent flow

A separate test series was performed in order to analyse the influence of the geometrical shape of the stenosis and the catheter piece Thus the effect of 30 mm long stenoses ($D_s = 46$ and 60%, respectively) and 30 mm long catheter pieces ($D_c =$ 47 and 61%, respectively) with their proximal and distal ends cut at right angles to the axis (i e the same geometrical shape of stenoses and catheter pieces as used in all the other experiments), were compared to the effects of stream-lined stenoses and catheter pieces The stenoses and catheter pieces were mounted in the rigid

walled and elastic walled vessels in the same way as described The static pressure loss across the different types of lumen area reductions was measured and calculated with a due respect to the character of the flow in the branch vessel A good agreement between the measured and the calculated values was found In general, the right-angled shape led to a greater pressure loss than the stream-lined This difference was most marked at high volumetric flow rates, while in the laminar flow region (Q_0 250 ml/min) no distinct difference between the right angled and the stream-lined shapes was found

Loss in pressure at pulsatile flow in vessels without and with lumen area reduction All pressure measurements performed at positions X_1 and X_2 at steady flow in the vessels were followed up by the same measurements at pulsatile flow, having the same mean static and stagnation pressure in the main vessel and the same mean values of Q_0 as at steady flow The peak pulse amplitude in the main vessel was varied from $4\,0 \times 10^3$ Pa to $10\,7 \times 10^3$ Pa (i e 30 to 80 mmHg), the pulse frequency was varied from 0 5 to 1 5 pulses per second and the shape of the pulse wave in the main vessel was identical to the one described in Part I (BJORNO & PETTERSSON), simulating the pulse wave in the distal aorta of a young healthy man

In the rigid walled vessel it was found that the per cent reduction of the static and the stagnation mean pressure of the pulse was equal to the per cent reduction of the same pressures at steady flow This was valid for both types and all degrees of lumen area reduction The reduction of the static and stagnation peak pulse amplitude followed that of their mean pressures, and thus, it was equal to the reduction of the pressures at steady flow

Also in the elastic walled vessel, the per cent reduction of both static and stagnation mean pressure of the pulse was equal to the per cent reduction of the pressures measured at steady flow However, the pulse amplitude attenuation deviated strongly from the attenuation course in the rigid-walled vessel The dispersion influence was strongest for the lowest volumetric flow rates Thus, the great pressure losses found at the highest volumetric flow rates reduced the relative influence of the dispersion

This deviation may be explained by, among other things, a geometrical dispersion in a waveguide system (consisting of the liquid core and the surrounding elastic vessel wall) This system will result in an interplay between the energy transport in the pulses in the liquid and the energy transport in stress waves in the wall material This interplay leads to a change in the shape of the pulse and a variation in the amplitude, with propagation along the vessel axis Also the wave reflection at the tip of the catheter should be of significance (KANAI et coll 1970)

The volumetric mean velocity at pulsatile flow in vessels without and with lumen area reduction The volumetric mean velocity at pulsatile flow was measured for the same types and degrees of lumen area reduction as for steady flow The reductions in the volumetric mean velocity at pulsatile flow were equal to those at steady flow

when the same types and degrees of lumen area reduction were compared This is to be expected due to the relation between the volumetric mean velocity and the static and stagnation pressures, as given in the foregoing section

Conclusions

On the basis of the experiments and theoretical analysis, the following conclusions may be drawn

(1) The experimental results obtained from the investigations of flow through stenoses may not be directly applied to the flow around catheters The loss processes are about the same in the two types of lumen area reductions, but the pressure loss for the same volumetric flow rate is much greater for catheters than for stenoses

(2) Simple fluid mechanics formulas may be used for the calculation of the volumetric mean velocity and the pressure loss in and for description of the flow through both rigid- and elastic-walled vessels with reduced lumen area at all volumetric flow rates This may facilitate further investigations

(3) There exists a 'critical annular lumen area reduction', in accordance with the well-known 'critical stenosis' For the same flow rates, the 'critical D-value' is much higher for the stenoses than for the catheters There also seems to exist a tendency to occurrence of higher critical D-values in elastic-walled vessels compared to rigid walled vessels

(4) The relative influence of the reduced lumen area increases for those volumetric flow rates where the lumen area reduction leads to a transition from laminar to turbulent flow in the branch vessel

(5) The shape of the lumen area reduction has a great influence on the pressure loss at high volumetric flow rates but is negligible in the pure laminar flow region

(6) In rigid-walled vessels, the per cent reduction of the pulse mean pressure and the per cent attenuation of the pulse peak pressure is equal to each other, and to the per cent reduction in pressure at steady flow In elastic-walled vessels, the per cent reduction of the pulse mean pressure also is equal to the per cent reduction in pressure at steady flow These facts will facilitate future investigations However, the per cent attenuation of the pulse peak pressure in the elastic-walled vessels deviates strongly from the one in rigid-walled vessels

SUMMARY

Experiments and a simple theoretical analysis have been performed concerning the flow through circular (stenosis) and annular (catheter piece) lumen area reduction of rigid and elastic-walled vessels Both steady and pulsatile flow at various volumetric flow rates were investigated A good agreement between the experimental and the analytical results has been found A critical annular lumen area reduction exists on a par with the well known critical stenosis The strongest reduction in pressure and in volumetric flow rate was caused

by the catheter pieces, compared with the stenoses The per cent reduction in pulse mean pressure and in volumetric mean velocity at pulsatile flow was equal to the per cent reduction in pressure and volumetric mean velocity at steady flow The influence of the geometrical shape of the stenoses and the catheter pieces is further discussed

ZUSAMMENFASSUNG

Experimente und eine einfache theoretische Analyse der Durchstromung durch eine zirkulare (Stenose) und annulare (Katheterstuck) verminderte Lumenfläche von Gefässen mit starren und elastischen Wänden wurden durchgefuhrt Sowohl gleichmässige als auch pulsierende Durchstromung bei verschiedenen volumetrischen Durchflussgeschwindigkeiten wurden untersucht Eine gute Übereinstimmung zwischen den experimentellen und den analytischen Ergebnissen wurde gefunden Eine kritische annuläre verminderte Lumenfläche besteht, die mit der wohlbekannten kritischen Stenose korrespondiert, die grosste Verminderung im Druck und der volumetrischen Durchflussgeschwindigkeit wurde durch die Katheterstücke hervorgerufen, die im Vergleich zu den Stenosen und der prozentuellen Verminderung im mittleren Pulsdruck und der mittleren volumetrischen Geschwindigkeit bei pulsierendem Druck gleich der prozentuellen Verminderung im Druck und der mittleren volumetrischen Geschwindigkeit bei gleichmässiger Durchstromung gleich war Der Einfluss der geometrischen Form der Stenosen und der Katheterstucke wird weiter diskutiert

RÉSUMÉ

Les auteurs ont fait des expérimentations et une analyse theorique simple du débit à travers la réduction circulaire (sténose) et annulaire (morceau de catheter) de la surface de la lumière de vaisseaux à parois rigides et élastiques Ils ont étudié les debits constants et les debits pulsatiles à différents taux de débit volumétrique Ils ont constate une bonne concordance entre les resultats expérimentaux et l'analyse théorique Il existe une reduction critique de la surface annulaire de la lumière vasculaire correspondant a la sténose critique bien connue, ce sont les morceaux de cathéter qui réduisent le plus la pression et le taux de debit volumetrique par comparaison avec les sténoses, le pourcentage de reduction de la pression moyenne pulsatile et de la vitesse moyenne volumetrique en débit pulsatile est égal au pourcentage de reduction de pression et de vitesse moyenne volumetrique en debit constant Les auteurs complètent l'etude de l influence de la forme geométrique des sténoses et des morceaux de cathéter

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EFFECT OF VASOPRESSIN ON HUMAN RENAL CIRCULATION INVESTIGATED BY ANGIOGRAPHY AND A DYE DILUTION TECHNIQUE

JAN GOTHLIN

Contradictory results regarding the effects of vasopressin on angiography in dog and man have been reported The same holds true for the influence of the drug on the renal circulation in animal Furthermore, it is often stated that tumour vessels are *not* influenced by vasoconstricting drugs even if common experience indicates the contrary Therefore, it seemed appropriate to elucidate the reasons for these discrepancies

Material and Methods

The material comprised four groups of patients, selective nephroangiography was performed in three

(1) Twelve patients with apparently normal kidneys were examined before and 10 s, 3 and 5 min after rapid intraarterial injection of 0 1, 0 5 and 1 0 IU lysine–vasopressin (Postacton, Ferring, Sweden), each dose given to 4 patients

(2) Four patients with apparently normal kidneys were examined before and 15 min after intraarterial injection of 1 IU vasopressin

(3) Four patients with hypervascularized carcinoma were examined before, 1 and 4 min after intraarterial injection of 1 IU vasopressin

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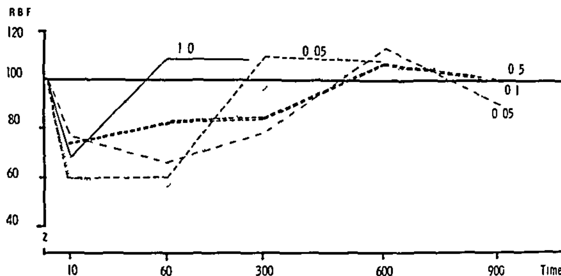


Fig 1 Renal blood flow variations in per cent in normal kidneys before (100 %) and at varying intervals (in seconds) after intraarterial administration of 0 05 to 1 0 IU of lysine-vasopressin Initial decrease, to some extent dose related, of RBF to 50 to 80 per cent of the control values There is a subsequent rise of flow over control values followed by a normalization

(4) The fourth group, consisting of 6 patients with apparently normal kidneys and 3 with hypervascularized carcinoma, was examined with a dye dilution technique in connection with conventional nephroangiography The determinations were made before, 10 s, 1, 5, 10 and sometimes 15 min after rapid intraarterial bolus injection of 0 05, 0 1, 0 5 and 1 0 IU lysine-vasopressin

The nephroangiography was performed with a 60 cm catheter (ID/OD 1 4/2 2) with an end-hole Ten ml (in carcinoma 20 ml) of meglumine-metrizoate (Isopaque Cerebral, Nyegaard, Norway) were injected by a high pressure syringe (Mark II, Medrad, USA) with a rate of 8 ml/s (in carcinoma 12 ml/s) The series used was one film/s for 12 s

Renal blood flow (RBF) was determined by injecting a bolus of 0 3 ml of indocyanine green (Cardio Green, Hynson, Westcott and Dunning, USA) into the renal artery and at the same time drawing blood from the renal vein via an 80 cm catheter with four side-holes, inserted via the femoral vein The blood passed a spectrophotometer, the deflections of which were recorded on a potentiometer-writer by a straight linear potentiometer The integration of the curves was made by cutting out and weighing copies of the curves The calculation of RBF was made according to a modified Stewart-Hamilton formula In addition, calculation was made of the mean transit time (MTT) and appearance time (AT) of the dye in the vein (For description of the technique and the mode of calculation, see GÖTHLIN & OLIN 1973)

Results

After administration of 0 05 to 1 0 IU lysine-vasopressin in normal kidneys the RBF decreased initially to 50 to 80 per cent of control value (Fig 1) This depression


a


b


c


d

F g 2 Selec ve nephroang ogranh

Table

Summary of the findings at nephroangiography at different intervals after administration of vasopressin compared with control + increase, 0 no change, − decrease

Time (s)	Arteries				Contrast medium in cortex	Veins		
	Emptying time	Width	Details	No		Appearance time	Concentrat of medium	No
10	+	(−)	+	+	−	−	+	−
180		0	−0+	0	+ +	− −	+ + +	+ +
300		0	0	0	+	− −	+ +	+

lasted more than one minute and was followed by an increase of flow to about 10 per cent over control values, lasting for a few minutes and then followed by a normalization of the RBF A tendency to a more marked decrease in RBF with increasing doses of vasopressin was observed No consistent changes in AT or MTT occurred

The changes in the RBF were reflected at angiography by initial spill-back of contrast medium into the aorta (Fig 2 b), prolonged emptying time of the arteries (Fig 3 b) and increased information of details in the arteries (Table) The accumulation of contrast medium in the cortex decreased (Fig 3 c) The contrast medium was earlier visible in the main renal vein and displayed slightly increased concentration The number of visible veins also increased (Fig 3 c, Table)

When the RBF increased over control value, no spill-back of contrast medium occurred (Fig 2 c) The emptying time of the arteries decreased below control value and the information diminished The accumulation of contrast medium in the cortex increased (Figs 3 c, 4 c) as well as the number of small veins visible (Fig 4 c, Table) The AT for contrast medium in the renal vein was further decreased The changes described were most marked in the films obtained 3 min after the drug injection but were to some extent discernible in the 5-min film (Figs 2 d, 3 d, 4 d)

In films obtained 15 min after the administration of vasopressin no differences compared with controls were observed

The RBF after vasopressin administration in hypervascularized carcinoma demonstrated (Fig 6) an initial marked increase to 120 to 150 per cent of control values lasting about one min At angiography a decreased arterial emptying time was found When films taken at the same time after injection of contrast medium in the two series were compared (Fig 5), the contrast medium in the control series remained in the main renal artery while 60 s after the injection of the drug only peripheral arteries were visible and large amounts of contrast medium were present in the intrarenal vein

In the series obtained immediately after vasopressin, the larger arteries were less well outlined but the delineation of the tumour was improved Over all, there was no diagnostic improvement

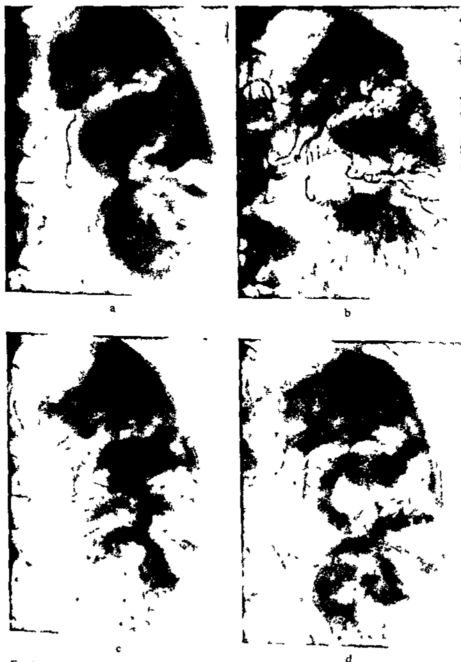


Fig 3 Same kidney as in Fig 2 0 5 ... arteries visible b ... medium remainir ... vasopressin Con ... concentration of ...

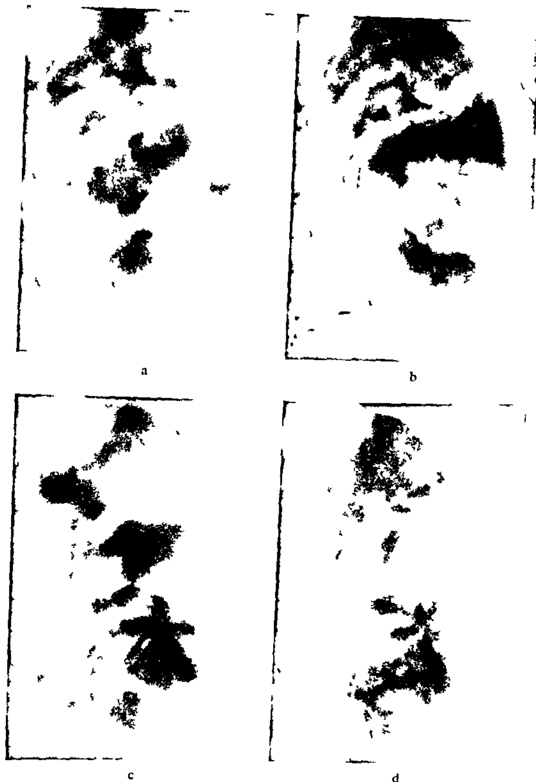


Fig 4 Same kidney as in Figs 2 and 3 4 s after end of injection of contrast medium a) Control b) 10 s after vasopressin Intrarenal arteries just emptied A larger number of veins seen than in (a) c) 3 min after vasopressin Abundant veins Cortex less well filled than in control (cf with Fig 3 c) d) 5 min after vasopressin Compared with Fig 3 d much contrast medium has left the veins

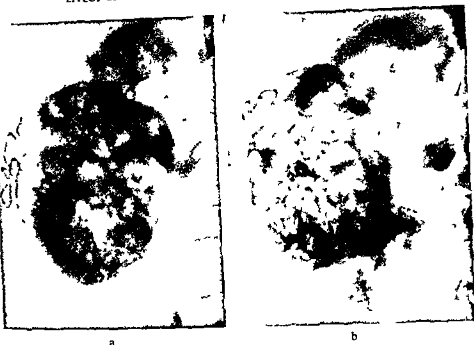


Fig 5 Selective nephroangiography of hypervascularized carcinoma Films are exposed at the same time after onset of injection of contrast medium a) Control b) 60 s after intraarterial injection of 1 IU vasopressin No contrast medium left in the renal artery indicating increased blood flow

The AT of indocyanine green in the main renal vein of kidneys with carcinoma was much shortened compared with normal kidneys (0 1 to 0 5 s compared with about 4 s in normal kidneys)

Three min after the vasopressin administration the RBF was reduced (Fig 6) to about 80 per cent of the control values lasting 1 to 2 min before normalization At angiography some spill back of contrast medium into the aorta occurred and the emptying time of the arteries was slightly prolonged but otherwise no significant changes compared with control values were observed

Discussion

In the experimental work on dogs by NYLANDER (1967) doses of 0 18 to 1 8 IU/kg bodyweight of lysine–vasopressin were given as infusion for 5 min before angiography, performed in the phase where the RBF was increased above normal At angiography in man 3 to 5 min after vasopressin administration only the following of his statements could be confirmed Increased accumulation of contrast medium in the cortex, increased concentration of medium in the veins, increased number of small veins visible His conclusion that vasopressin reduces renal vascular tone and increases

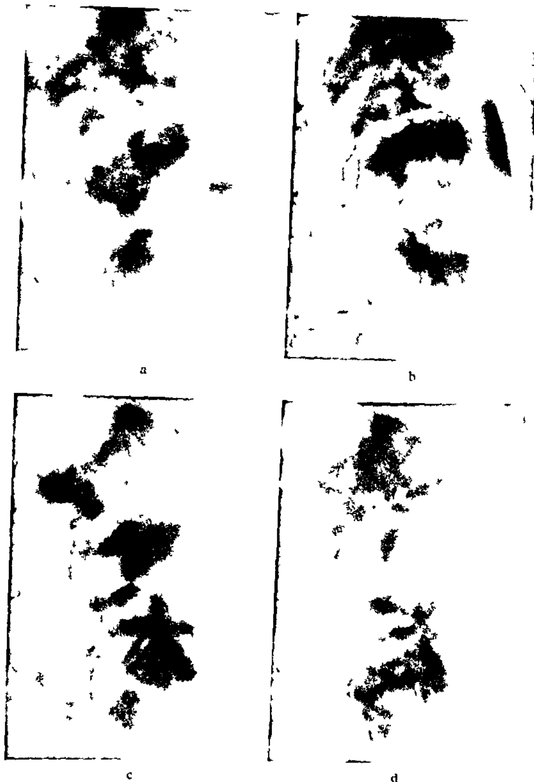


Fig. 4. Same kidney as in Figs. 2 and 3. 4 s after end of injection of contrast medium. a) Control. b) 10 s after vasopressin. Intrarenal arteries just emptied. A larger number of veins seen than in (a). c) 3 min after vasopressin. Abundant veins. Cortex less well filled than in control (cf. with Fig. 3 c). d) 5 min after vasopressin. Compared with Fig. 3 d much contrast medium has left the veins.

injection of arginine-vasopressin stated that low concentrations of the drug did not affect the RBF but that higher doses reduced nutritional flow in both cortex and medulla As the measurements of the RBF were made under vasopressin infusion there were perhaps no possibilities for increased renal blood flow to develop which then should be opposite to what occurs in the liver (BARR et coll 1975)

CARLSSON & ERIKSON observed no changes of the tumour vessels after the administration of vasopressin It is commonly stated that such vessels have no contractile elements In the present cases of renal carcinoma, however, the RBF initially increased considerably after vasopressin as demonstrated both at angiography and by the dye dilution technique The subsequent reduction is contrary to the response in normal kidneys The reason for this reverse reaction of renal blood flow is not clear but maybe tumour vessels really do react to vasoconstrictors

The fact that contrast medium could be detected earlier in the renal vein in normal kidneys after administration of vasopressin than at control despite the decreased RBF and unchanged AT demonstrated with a dye dilution technique may be explained by shunting so that larger quantities of contrast medium appear early in the vein This has been reported to occur in rabbit kidneys, demonstrated with magnification angiography (GÖTHLIN et coll) and probably occurs in the juxtamedullary glomeruli The much doubted statement by TRUETA et coll (1947) that juxtamedullary shunting is possible, is probably correct There seems to be no other logical explanation for the phenomenon Mainly the juxtamedullary glomeruli of rabbit kidneys seem to function after high doses of vasopressin (GÖTHLIN, unpublished data)

The biphasic effect of vasopressin on normal renal circulation is not unique It appears also after angiotensin injected into the renal artery (GÖTHLIN) and in the liver after selective celiac infusion of vasopressin (BARR et coll 1975) The explanation is probably that a reactive hyperemia after the initial ischemia occurs

The slightly less well demarcated outlines of the larger arteries on films obtained immediately after vasopressin administration has not previously been reported The reason is not clear but the appearance may be due to an alteration of the permeability of the vessel walls

Conclusion

Vasopressin induces a biphasic response in renal blood flow in normal kidneys with an initial decrease followed by a compensatory increase above normal This response is reflected both at angiography and with a dye dilution technique and may explain the contradictory results reported by other authors After administration of vasopressin there is evidence of shunting in normal kidneys A reverse response to vasopressin in hypervascularized carcinoma occurs, suggesting that tumour vessels react to vasoconstricting drugs

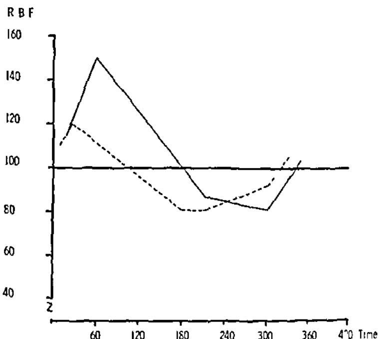


Fig 6 Renal blood flow variation in per cent in kidneys with hypervascularized carcinoma before (100 %) and at varying intervals (in seconds) after intraarterial administration of 1 IU of lysine-vasopressin Early increase of RBF to 120 to 150 per cent of control values The subsequent drop in RBF is not marked The reaction of the RBF is contrary to the one in normal kidneys (cf with Fig 1)

the blood flow is valid at this period (3 to 5 min) after the drug administration, but only then His other findings, as dilatation, elongation and increased tortuosity of the arteries and increase in kidney size, could not be confirmed If anything, they could perhaps be explained by species differences as these findings are not found in rabbits (GÖTHLIN et coll 1975) Increased width of renal veins is demonstrable in rabbits (GÖTHLIN et coll) but not in man

CARLSSON & ERIKSON (1970) in man, using intraarterial slow injection of 0 2 to 0 3 IU of vasopressin (Sandoz, Basel, Switzerland) probably immediately before the angiography, reported decreased diameter of the renal arteries, increased spill-back of contrast medium into the aorta, unchanged length of the arterial phase and unchanged venous appearance with unchanged or decreased venous filling They condluded that 'the circulation time' was unchanged and stated that vasopressin increased the vascular resistance and decreased the flow In the present investigation, no change of the renal size was found which is in agreement with the statements of these authors but contrast medium appeared earlier in the veins contrary to their findings

It may be stated that NYLANDER and CARLSSON & ERIKSON both mainly drew the correct conclusions regarding their results The differences are attributable to the different intervals between the drug administration and the angiography

The effect of vasopressin on renal circulation in animals has been more extensively analyzed by use of gases, flow-meters, microsphere technique and thermocouples

BERDE et coll (1961) and BARER (1963) recorded an increase in the RBF after a short initial decrease GRANGSJÖ & PERSSON (1968) using continuous intravenous

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CATHETER ANGIOGRAPHY AND VENOUS THROMBOSIS

BRITT-MARIE WIDESTADH, S-E BERGENTZ and E BOIJSEN

Postoperative, deep venous thrombosis occurs in 30 to 50 per cent of patients above 40 years of age (FLANC et coll 1969, among others) Only about one third of these have symptoms or signs No reports seem to be available on the frequency of venous thrombosis following angiography with catheterization of the femoral artery but this complication may be expected for several reasons (JACOBSSON & SCHLOSSMAN 1969) (1) The majority of the patients are old (2) The patients are lying supine for a relatively long time, both during and after the angiographic procedure (3) Following catheterization of the femoral artery a pressure is applied in the groin, first manually, later with a compression bandage or sand bag In spite of this, a hematoma usually develops, which may compress the vein (4) Thrombi are known to form on intravascular catheters due to an activation of the coagulation system This activation may be demonstrated as an increased platelet adhesivity and a consumption of fibrinogen (JACOBSSON 1969)

An evaluation of the frequency of deep venous thrombosis following angiography was performed using ^{125}I labelled fibrinogen for demonstrating the thrombi

Material and Methods The material consisted of 20 patients examined with aorto iliac femoral angiography The indication was intermittent claudication in 19 patients, aged between 50 and 81 years, and arteriovenous shunt in a 24-year-old patient

Submitted for publication 5 December 1975

SUMMARY

Vasopressin intraarterially injected in normal kidneys decreases the blood flow initially with a subsequent increase above normal. In hypervascularized carcinomas the response is reversed. Both findings are demonstrable with angiography and dye dilution technique.

ZUSAMMENFASSUNG

Intraarteriell injiziertes Vasopressin verringerte bei der normalen Niere die Durchblutung anfänglich mit einem nachfolgenden Anstieg uber das Normalniveau. Bei hypervaskularisierten Karzinomen ist die Antwort umgekehrt. Beide Befunde konnen mittels Angiographie und eine Farbstoffverdunnungstechnik dargestellt werden.

RÉSUMÉ

L'injection intraartérielle de vasopressine dans des reins normaux diminue d'abord le débit sanguin puis est suivie d'une augmentation au dessus de la normale. Dans les carcinomes hypervascularisés, la réponse est inversée. Ces deux résultats peuvent être mis en évidence par les techniques d'angiographie et de dilution de colorant.

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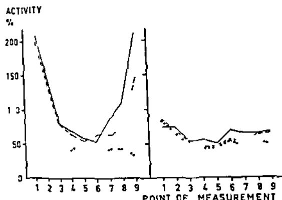


Fig 2 Activity data obtained in the 76-year-old patient with thrombosis in the right catheterized leg (left part of figure) Points 1 to 9 indicate the points of measurement from groin to lower part of the thigh High activity in the groin after the angiography and over the calf Right leg normal (right part of figure) = day 0 — day 5 —— day 8

They were lying in bed for 12 to 24 hours following the angiography The technique to demonstrate thrombosis is sensitive with practically no false negative results (KAKKAR et coll)

Thrombosis occurred only in the patient with the largest hematoma The thrombosis appeared at the site where the catheter had been inserted suggesting compression of the femoral vein as at least a contributory factor

The results indicate that the risk of deep venous thrombosis after catheter angiography is low but may increase if a major groin hematoma develops

SUMMARY

The occurrence of deep venous thrombosis following femoral angiography was evaluated in 20 patients with ¹²⁵I labelled fibrinogen In spite of the fact that the patients represented a high risk group thrombosis developed in one patient only

ZUSAMMENFASSUNG

Das Vorkommen einer tiefen venosen Thrombose nach einer Angiographie der A femoralis wurde bei 20 Patienten mit ^{125}I gezeichnetem Fibrinogen festgestellt Trotz dass diese Patienten eine Gruppe mit einem hohen Risiko reprasentieren entwickelte sich eine Thrombose nur bei einem Patienten

RESUME

Les auteurs ont etudié l apparition de thromboses des veines profondes après angiographie femorale chez 20 malades par fibrinogène marque avec ^{125}I Bien que ces malades representent un groupe a haut risque un seul de ces malades a presenté une thrombose

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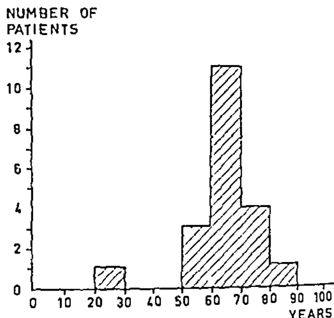


Fig 1 Age distribution of the patients

Sixteen patients were above 60 years of age (Fig 1) Percutaneous angiography was performed with a thin-walled catheter (OD 2 2 mm), which remained in the artery between 35 and 100 min, average 62 min The time of compression after withdrawal of the catheter varied but usually not exceeding 15 min

Thrombosis was diagnosed using the method of KAKKAR et coll (1970) After administration of iodine, 100 μCi of ^{125}I labelled fibrinogen were injected the day before angiography The activity over each leg was determined with a D A Pitman model 235 isotope localization monitor Measurements were performed before angiography and continued daily for at least 4 days afterwards Thrombosis was considered to exist if an increase of activity amounting to at least 20 per cent was found at one point

Results

The activity increased in all patients around the point where the catheter had been inserted, indicating a local hematoma but further down on the leg no increased activity was found, except in one patient aged 72 (Fig 2) Following catheterization of the right femoral artery, this patient had a marked increase in activity in the right calf beginning on the second day and remaining throughout the control period of 11 days She also had an unusually large hematoma at the point of insertion of the catheter preventing her mobilization Signs of thrombosis appeared one week following angiography For technical reasons, phlebography could not be performed

Conclusion

The patients in the present series represented a high risk group with regard to thrombosis They were elderly, and most of them had generalized atherosclerosis

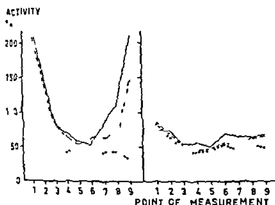


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ESTIMATION OF CORONARY ARTERY STENOSIS

Limitations of present methods

L BJÖRK and A O'KEEFE

Since coronary angiography became a standard procedure for evaluation of coronary artery disease, attempts have been made to quantify the degree of stenosis in the coronary arteries Most commonly a semiquantitative assessment of stenosis is based on visual inspection of full size, 70- or 100 mm films or cine films The degree of *stenosis* is arbitrarily expressed as percentage obliteration In most instances it is unclear whether the observer is referring to the diameter, the circumference or to the cross-section of the artery

Such methods are largely subjective Assessments may differ considerably between individuals and institutions Attempts have been made to measure coronary arteries (GENSINI et coll 1971, LEVIN et coll 1972, MACALPIN et coll 1973, RÖSCH et coll 1973 VAN TASSEL et coll 1972) and the authors have expressed varying degrees of confidence in their results Others have been critical about the possibilities of measuring small vessels in patients (SANDOR & ADAMS 1973, SILVERMAN 1971, SIMON 1973, Small vessel angiography 1973) and base their statements on well known factors in radiographic imaging such as size of the focal spot, object to film distance, et cetera They have also emphasized the limitations of the modern recording systems such as image intensifiers cine films and video recordings

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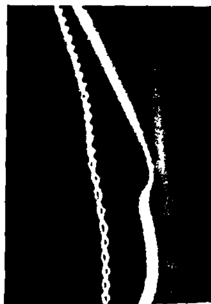


Fig 1 Stenosis (1 mm diameter) in a plastic tube (2 mm diameter) filled with Renografin 76 % and placed centrally in 15 cm water The image was recorded with a 70 mm camera, 18-cm cesium iodide image intensifier, 0 3 mm focal spot, 70 kV and 80 mR/frame

Since there seems to be some confusion regarding the possibilities of actually measuring coronary artery size on cine films, some simple experiments were performed using plastic tubes as models for coronary arteries and the best imaging system available at present

Material, Methods and Results

The experiment was to measure four straight plastic tubes with diameters varying from 1 5 to 5 mm The tubes were filled with Renografin 76 % They were placed horizontally and centrally in 15 cm of water and perpendicular to the recording beam to simulate the absorption and scatter generated by an average patient The image of these plastic tubes was recorded in the center of a Siemens 18-cm (7 inch) cesium-iodide image intensifier and a 70-mm camera was used The nominal focal spot size was 0 3 mm, exposure factors were 80 mR/frame and 75 kV The true diameter of the tubes was determined with a measuring microscope The inner diameter of the tubes was measured on the 70-mm films projected on a large screen The cross-sectional areas of the tubes were calculated from these measurements and compared with the true cross-sectional areas The large tube, 5 mm in diameter, could be measured relatively accurately, the deviation from the true cross-sectional area was 0 6 per cent As the tube diameter decreased, the error increased, with the 4-mm tube the deviation was 4 8 per cent, with the 3-mm tube 6 2 per cent and with the 1 5-mm tube the error in the estimation of cross-sectional areas was 16 per cent

In the second experiment a symmetrical diffuse stenosis was made in a plastic tube with an inner diameter of 2 mm This tube was filled with Renografin 76 %, curved in one plane and again placed centrally in 15 cm of water Images were obtained of the tube using the 70-mm camera and 80 mR/frame (Fig 1) as well as

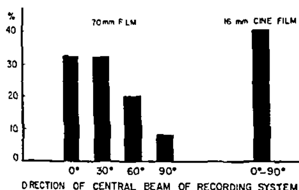


Fig. 2 Accuracy of angiographic measurements of stenosis of the plastic tube in Fig. 1 The deviation from the true cross sectional area is given in per cent

with a 16-mm cine camera and 8 mR/frame The diameters of the tube and the stenosis were determined with various incidences of the central beam corresponding to anteroposterior, 30 oblique, 60° oblique and lateral projections of the plastic tube The angiographic measurements of the cross sectional areas were then compared with the true cross sectional areas of the stenosis and of the tube Generally the angiographic measurements were not very accurate (Fig 2) As expected the incidence of the central beam had a great influence on the accuracy of the measurements The 70-mm camera had obvious advantages over the 16-mm camera which, as used in this experiment, is not taking full advantage of the capabilities of the recording system

Discussion

In these experiments the conditions for imaging were optimum and different from conditions present in patients in many respects The degree of magnification could be calculated exactly The tubes were straight except in the second experiment in which there was a curve in only one plane The object did not move and the tube was constantly filled with undiluted contrast medium

It appears that true measurements of coronary artery stenosis and of coronary arteries with diameters below 3 mm simply are not possible in patients even with the best recording systems commercially available This is not totally unexpected, but *it is important* to emphasize this limitation of the present imaging systems These findings partially explain the difficulty in estimating physiologic effects of anatomic lesions as they appear at coronary angiography

SUMMARY

From model experiments it is concluded that true measurements are not possible of coronary arteries or stenosis below 3 mm in diameter

ZUSAMMENFASSUNG

Aus Modellversuchen wird geschlossen, dass exakte Messungen der Koronararterien oder Stenosen unter 3 mm Diameter nicht moglich sind

RÉSUMÉ

D'apres une expérimentation sur modèle les auteurs concluent qu'il n'est pas possible d'effectuer des mesures exactes des artères coronaires ou de stenoses au dessous d un diamètre de 3 millimètres

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TECHNIQUE OF CORONARY ANGIOGRAPHY

UNO ERIKSON

Selective coronary angiography is essential in the preoperative examination of coronary heart disease Two main approaches are recommended, transbrachial and transfemoral The first technique, introduced by SONES (1967), involves arteriotomy and one catheter with four side-holes near the end-hole is used, both for the left and the right coronary arteries The main proponent of the transfemoral technique is JUDKINS (1967) Two specially formed catheters with end-holes are used for the respective arteries

These procedures involve risks Even fatal complications have occurred, the mortality risk varying from zero to two per cent as estimated from data in the literature (KALTENBACH & LICHTLEN 1971, CHAHINE et coll 1972) The material of 500 patients at this hospital examined by the transfemoral technique and compiled over a five year period from 1969 to 1974 included one fatal complication in 1969 and one in 1970

The risks should be divided into those common to angiography in general and those specific to patients with heart disease

The risk in the first group involves the puncture technique (needle, site of puncture) and the handling of guide wires and catheters Some of these aspects have been considered by ERIKSSON & JORULF (1970), the frequency of complications requiring surgery in their series was 0 3 per cent Concerning the cardiac complications, the severity of the heart disease must be considered When a new technique is introduced, it tends to be used mainly on patients who are more ill and thus present an increased

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ZUSAMMENFASSUNG

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Fig. 2 Cine frames of right and left coronary sinuses and coronary arteries including segments adjacent to orifices in a 51 year-old male

The criterion for success was a distinctly visible coronary artery from the sinus to its peripheral branches possibly with retrograde collateral filling and an angiogram which could be used for routine diagnosis

The ECG was monitored continuously The contrast medium was 5 to 8 ml of Urografin 60 % (Na and meglumine salt Schering AG) or Isopaque Coronar 60 % (Nyegaard & Co) A small test injection was given and all injections were made by hand Roentgen equipment Siemens and Philips biplane cine The film focus distance was 100 cm and the film speed 75 frames/s

In about 30 per cent of the cases the right coronary artery catheter was used also for left ventricular angiography including left ventricular densitometry In 16 patients Cordis femoral coronary catheters were also used (Cordis Corp USA)

Results

The right coronary artery The new Kifa catheter was employed in 67 patients the grey variant in 30 and the green one in 37 The examination was unsuccessful in 3 patients in one of these a satisfactory angiography was achieved following introduction of a Cordis catheter

The left coronary artery The new Kifa catheter was used for the left coronary artery in 64 patients the grey catheter in 29 and the green one in 35 The examination was unsuccessful in 17 patients (6 and 11 respectively) A satisfactory angiography following introduction of a Cordis catheter was achieved in 7 cases of the 17

The green material was somewhat easier to use Especially the right coronary artery was rapidly reached The left femoral coronary catheter was only gradually

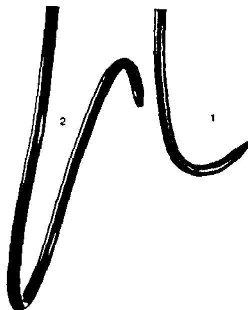


Fig. 1. Lateral view of the right (1) and a.p. view of the left (2) coronary arterial catheter. The tip of the left one deviates to the left.

risk. Once the method has become accepted it is employed on a relatively larger number of patients with borderline disease and even patients who prove to be free from heart disease. Concurrently the technical skill of the catheterization team increases, which also reduces the risk of the procedure (PRIDIE et coll. 1975).

There is still a need for a safer procedure in coronary angiography. This report describes the experiences from a new design of catheters.

Catheters, Technique and Procedure

In the present series of patients two different types of preshaped catheters were used, one for the left and one for the right coronary artery. The catheter tubing is made of polyethylene and has a very smooth surface. It is called the new Kifa Ödman-Ledin tubing (Siemens-Elema, Sweden). Its improved surface characteristics have been achieved by a new manufacturing process. The dimensions for both types are: (1) Grey, inner diameter 1.8 mm and outer diameter 2.8 mm and (2) Green, inner diameter 1.2 mm and outer diameter 2.4 mm. The length of the catheters is 100 cm. The ideal shape of the new Kifa catheters is illustrated in Fig. 1. One side-hole is located 15 mm from the tip, the reason for this being to enable simultaneous filling of the sinus adjacent to the artery, to allow filling of the very beginning of the artery and to avoid deleterious effects of occlusion by the catheter. Local anaesthesia with 10 ml Xylocaine was applied after a premedication of 25 mg promethezine chloride (Lergigan) and 50 mg pethidine chloride. The conventional procedure for *coronary angiography* by the transfemoral technique was followed. If the catheter failed to enter the coronary artery appropriately it was replaced by the Cordis transfemoral coronary catheter. If this also proved unsuccessful the procedure was terminated.

ZUSAMMENFASSUNG

Eine neue Herstellungsmethode und die neuen Formen des linken und rechten Katheters fur Koronarangiographie mittels transfemoraler Katheterisierung steigern die Sicherheit der Koronarangiographie durch Verkurzung der Untersuchungszeit und Vermeidung der Risiken, die mit dem Verschluss der Arterien durch den Katheter verbunden sind Die gleichzeitige Fullung des Sinus und der gesamten A coronaria erhoht die anatomische Information Die Druckuberwachung ist unnotig

RÉSUMÉ

Un nouveau procédé de fabrication et les nouvelles formes des cathéters pour l examen par voie *femorale des artères* coronaires droites et gauches augmentent la securite de l'angiographie coronaire en reduisant la durée d'examen et en évitant les risques que comportent l occlusion des *artères par le cathéter* *Le* remplissage simultane du sinus et de l'artère coronaire en entier depuis son origine augmente les informations anatomiques Il n'est pas nécessaire de faire une surveillance de la pression

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modified into its final shape (Fig 1) In the last 30 patients the examination was invariably successfull In all cases the sinus was filled through the side-hole The peripheral filling was good

Ventricular fibrillation induced in one patient was successfully defibrillated and normal rhythm restored. One patient complained of angina No other complications were observed

Discussion

The shape of the transfemoral coronary catheter is of particular importance when exploring the left coronary artery The proximal curve supports the catheter against the anterior wall of the aorta and enables the tip to remain stationary during the injection The distal curve must have an angle of less than 70° to allow introduction of the catheter into the ostium The tip bends to the left in order to avoid entering the non-coronary sinus The right coronary artery is relatively easy to catheterize, especially with the green catheter Care must be taken not to introduce the catheter too far into the right artery when using the green variant, because of its smaller diameter

The side-hole reduces the risk of total occlusion of a narrow artery and its location 15 mm from the tip is important in order to have the hole in the aorta It also provides for satisfactory filling of the sinus and the first part of the artery, which may be difficult to achieve with catheters without a side-hole (Fig 2) The side-hole enables blood and small gas bubbles to be aspirated even if the tip of the catheter is close to the wall of the vessel This also obviates the inconvenience of pressure-monitoring during the catheterization About 15 per cent of the contrast medium escapes via the side-hole and the injected amount should be increased accordingly

In 20 patients the preformed right coronary catheter was also used for left ventricular angiography This reduces the examination time and therefore probably also the risk of complications

Selective coronary angiography often presents problems at catheterization because of difficulties in finding the origins of the arteries and the different sizes of the aorta, which causes instability of the catheters

The described catheters of the new material seem to satisfy the need for different types of femoral coronary catheters

SUMMARY

A new manufacturing process and new shapes of the left and right catheters for coronary angiography by the transfemoral route increase the safety of the examination by reducing the time and avoiding the risks involved in catheter occlusion of the arteries The simultaneous filling of the sinus and the whole coronary artery from its origin increases the anatomic information Pressure-monitoring is unnecessary

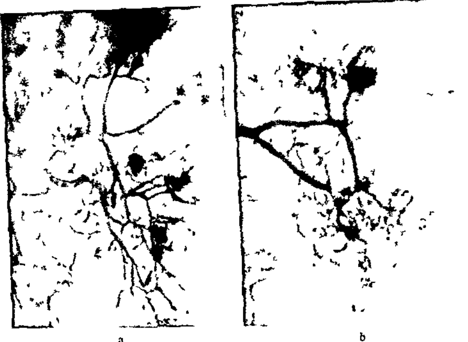


Fig. 1 Case 1 a) Large carcinoma partly richly vascularized with multiple large pseudoaneurysms in a man aged 64 The tumour was *inoperable* b) Seven months later after treatment with intra muscular progesteron injections The vascular appearance slightly altered with regression of pseudoaneurysms but generally increased neovascularity

with radiation therapy In two of these patients some change in tumour vascularity had occurred (cases 1, 5) The 5 year survival in this small series was 38 per cent (5 patients)

Discussion

It is evident that there may be variations in the growth rate of renal carcinoma, probably related to the state of immunologic defence mechanism of the host The growth of a renal tumour is demonstrable in cases that have for some reason not been operated upon JOHNSSON (1946) described 4 cases examined during expectancy with repeat urography In one case the tumour grew only 7 cm in diameter in the course of 5 years but retained its round shape and was well defined After an additional 5 years the patient was examined again but not operated upon The tumour had invaded adjacent tissue and metastasized to the lungs In another case an increase in diameter of only 0 5 cm in one year was demonstrated and the tumour was well defined Two other patients were re-examined after 5 and 8 months respectively, but no change in size or shape of tumour could be demonstrated

Conventional urography is however, not the method of choice to evaluate tumour growth as infiltrative spread into surrounding tissues will not be revealed High

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GROWTH RATE OF RENAL CARCINOMA AS DEMONSTRATED BY REPEAT ANGIOGRAPHY

L EKELUND and K JONSSON

A patient with the diagnosis of renal carcinoma is usually operated upon If for some reason surgery is not performed the growth may be followed by repeat angiography By reviewing materials from two university clinics 13 such cases have been collected and are now reported

Material and methods Since 1964 repeat angiography was performed in 13 patients (10 males and 3 females) with renal carcinoma Their ages at the first angiography ranged between 42 and 74 years The diagnosis was confirmed by surgery or autopsy in 9 of the cases In one case lymph node biopsy suggested metastasis from a papillary renal carcinoma and in the remaining 3 patients clinical and radiologic examinations indicated renal carcinoma Selective nephroangiography was performed in all cases but one (with few exceptions in two projections) At additional cavography in 4 patients occlusion of the renal vein was found Three patients had been treated with progesteron injections, one of these with additional radiation therapy, and another patient with radiation therapy alone

Results The time interval between the angiographies and the change in tumour size appears in the Table Tumour progression was evident in 7 cases with a maximum linear diametric growth rate of 0 5 cm/2 5 months (cases 3, 7, 8, 10, 11, 12, 13) In one case (not confirmed by microscopy) temporary spontaneous regression was found (case 9) The tumour size was unchanged in 5 cases, re-examined after 1 to 30 months Three of these patients had been treated with hormones, one in combination

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Table

The course of renal carcinoma in the present material

Case	First angiography		Time interval (months)	Second angiography		Time interval (months)	Third angiography	
	Tumour size (cm)	Tumour vascularity		Tumour size (cm)	Tumour vascularity		Tumour size (cm)	Tumour vascularity
1	18×11	Abundant	7 (Progesteron treatment)	Unchanged	Changed			
2	14 12	Abundant	5 (Progesteron treatment)	Unchanged	Unchanged			
3	5 5×4	Moderate	2 5	6×4	Unchanged			
4	12×12	Abundant	30	Unchanged	Unchanged			
5	9×13	Abundant	3 (Progesteron treatment)	Unchanged	Unchanged	3 5 (radiation therapy)	Unchanged	Reduced
6	12×8	Abundant	1	Unchanged	Unchanged			
7	5 5×6	Avascular	25	6 5×6 5	Sparse			
8	Upper pole	Sparse	12	Increased	Increased	4 (radiation therapy)	Increased	Increased
9	12×12	Abundant	12	Decreased	Partly decreased			
10	1×1	Moderate	3	1×1	Unchanged	23	2×3	Unchanged
11	1×1 5	Sparse	9	2 5×2	Increased			
12	5×8	Moderate	71	8×13	Changed			
13	2×1 5	Moderate	60	5 5×5 5	Partly reduced			

Fig 2 Case 3 Man aged 7[illegible]

Fig 3 Case 5 Man aged 57 a) Large carcinoma with abundant neovascularity and arteriovenous shunting At inferior cavography occlusion of the vein was found The tumour was considered inoperable b) 6 5 months later after treatment with hormones and radiation therapy Size of tumour unchanged but decrease in vascularity


a

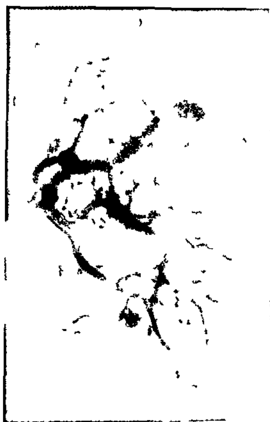

b

Fig. 2. (For legend see opposite page.)


a


b

Fig. 3. (For legend see opposite page.)


a


b

F g 5 Ca o . ..

u 20


a


b

F g 6 Case 10 Man aged 74
a tumou measu n
b) 26 mon hs la er

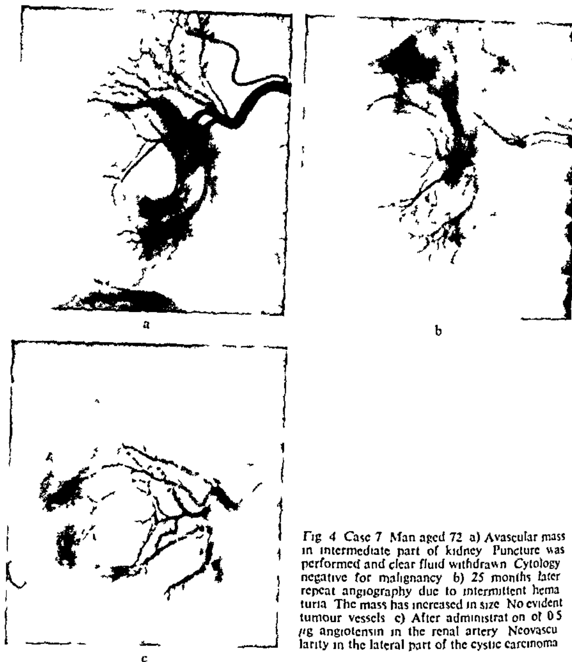


Fig 4 Case 7 Man aged 72 a) Avascular mass in intermediate part of kidney Puncture was performed and clear fluid withdrawn Cytology negative for malignancy b) 25 months later repeat angiography due to intermittent hematuria The mass has increased in size No evident tumour vessels c) After administration of 0 5 μg angiotensin in the renal artery Neovascularity in the lateral part of the cystic carcinoma

dose urography supplemented by tomography (EVANS 1954, BOSNIAK 1974) allows, as a rule, a differentiation between benign cysts and *necrotic or cystic* tumours However, this method was not used in the present material Assessment of tumour vascularity requires angiography, which may give further information of the extent of the tumour The observation period in the present material ranges between 1 month and 6 years Tumour progression could be demonstrated in 7 cases with a maximum linear diametric growth rate of 0 5 cm/2 5 months (case 3) This may be compared with the growth rate of early carcinomas of the colon or rectum Thus, WELIN et coll (1963) found carcinomas to have a linear diametric growth



Fig 8 Ca
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sion of microscopically confirmed pulmonary metastases without removal of primary carcinoma in the kidney has been reported in one case by LJUNGGREN et coll (1959)

The importance of performing nephroangiography in more than one projection is illustrated in case 11, in which the diagnosis was overlooked at the first examination, where only films in a p projection were obtained (Fig 7) In retrospect abnormal vessels are seen medial to the renal pelvis, which is superimposed on the rest of the tumour Very likely the diagnosis had been settled already at the first angiography if also oblique projections had been used

The interesting possibility of the coexistence of carcinoma and cyst is brought up by case 7 Three to five per cent of solitary cysts in some reported series has contained neoplasm (REHM et coll 1961, BRENNAN et coll 1962) The unanswered question is if carcinoma was present also at the time of the first investigation when cytologic examination of aspirated fluid was negative for malignancy The same case also illustrates the value of pharmacoangiography with angiotensin (EKELUND et coll 1972) which made possible the diagnosis of malignancy at a second examination



Fig 7 Case 11 Woman aged 42 a) Selective angiography of right main renal artery (the kidney was also supplied by an upper polar artery proved at preceding aortography) Only a p view was obtained which was considered normal Retrospectively tiny abnormal vessels seen medial to renal pelvis (→) and some neovascularity probably hidden by contrast medium in renal pelvis b) 9 months later, repeat angiography because of persistent hematuria The carcinoma now measuring 2 5 cm × 2 cm After nephrectomy the patient is alive and healthy 9 years later

rate of 0 09 to 0 75 mm/month, and in a recent series (EKELUND et coll 1974) examined on several occasions with double contrast radiography of the colon a linear diametric growth rate of 0 06 to 2 00 mm/month (median 0 52 mm) was found

Regressive changes are not uncommon in renal carcinoma and spontaneous healing was first reported by HULTQUIST (1944) BARTLEY & HULTQUIST (1950) reported on 26 autopsy cases with different healing stages and assumed that the regression could lead to complete disappearance of tumour tissue Similar observations were reported by ZAK (1957) Only one report on angiography in cases of spontaneously healed tumours seems to have been published (BARTLEY & HELANDER 1962) In one of their 3 cases, considered to represent different stages of spontaneous healing, the tumour size was unchanged during 10 years In this case a few pathologic vessels were observed, in the other 2 cases no abnormal vessels were discernible In the present case 4 a large carcinoma retained its size during an observation time of 2 5 years until nephrectomy was performed A decrease in tumour size has been observed by OLSSON (1973) in one case In case 9, a spontaneous regression of the renal mass, as well as of pulmonary metastases was observed at re-examination 12 months following the first angiography (Fig 5) Later the condition deteriorated, the metastases progressed and the patient died but no autopsy was performed Spontaneous regres-

maximum linear diametric growth rate of 0 5 cm/2 5 months Of the 5 cases with unchanged tumour size only 3 were microscopically examined Unfortunately it is not mentioned in the microscopic report if healing processes were present or not At present there are no radiologic appearances indicating healing It seems possible that cystic renal tumours with a thick capsule and devoid of pathologic vessels at angiography represent healing stages Detailed microscopy of such cases may throw more light upon this problem Such investigations could possibly explain why some tumours do not increase in size during long periods of time It is also possible that they could in the future influence the treatment nephrectomy being substituted by resection of a tumour with marked regressive changes For the moment, however, every mass, which is not proved to be a cyst, must be handled as a malignant lesion

SUMMARY

Thirteen patients with renal carcinoma, primarily not operated upon were re-evaluated 1 to 71 months after the first nephroangiography Tumour progression could be demonstrated in 7 cases with a maximum linear diametric growth rate of 0 5 cm/2 5 months. The reasons for absence of growth in the remainder are not apparent, but probably related to the state of immunologic defense mechanism of the host

ZUSAMMENFASSUNG

Dreizehn Patienten mit einem Nierenkarzinom die primär nicht operiert worden waren, wurden 1 bis 71 Monate nach der ersten Nephroangiographie erneut untersucht Ein Tumorzuwachs konnte in 7 Fallen mit einer maximalen linearen Zuwachsrate des Diameters von 0 5 cm/2 5 Monate nachgewiesen werden Die Grunde fur das Fehlen eines Zuwachses bei den restlichen Fallen ist nicht klar hangt aber wahrscheinlich mit dem immunologischen Verteidigungsmechanismus zusammen

RESUMÉ

Treize malades atteints de cancer du rein qui n avaient pas eté opérés ont ete réexaminés de 1 à 71 mois après la première nephroangiographie La progression de la tumeur a pu être mise en évidence dans 7 cas avec un taux de croissance linéaire maximum du diamètre de 0 5 cm/2 5 mois Les raisons de l absence de croissance dans les autres cas ne sont pas apparents mais elles sont vraisemblablement en rapport avec l etat du mecanisme de defense immunologique de l hôte

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a



b

graphy

Even if a tumour cyst usually does not contain clear fluid without malignant cells this may occur Therefore, examination of the cyst after injection of a contrast medium should be performed In some cases this must be supplemented by high dose nephrotomography to determine the thickness of its wall A benign cyst has a smooth thin wall whereas a tumour cyst has a relatively thick capsule or in some cases a local thickening of the wall

Four cases with occlusion of the renal and inferior vena cava were considered inoperable, two were treated with hormones, one with hormones and radiation therapy and one with radiation therapy alone In 3 of these patients the tumour had not increased in size after 7, 5 and 6 5 months, respectively In one of these cases, a definite reduction in vascularity occurred (Fig 3) If this may be attributed to the therapy is uncertain, even if favourable therapeutic results with hormones have been reported (WOODRUFF et coll 1967)

In the present material tumour progression was evident in 7 of 13 cases with a

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NEPHROANGIOGRAPHY IN AMYLOIDOSIS

Å FORSSELL and B ISAKSSON

Although renal amyloidosis is not uncommon only one report has been published on angiography in this disease (EKELUND & LINDHOLM 1974) They described six cases all with angiographic abnormalities, a common feature was narrow peripheral intrarenal arterial branches Contrary to previous statement (BARCLAY et coll 1960), thrombosis of the renal veins was not observed in any of these cases

During recent years nephroangiography has been performed at this hospital in 16 cases of microscopically confirmed renal amyloidosis The results are now reported as they appear to complement previous observations

Material and Methods

The material consisted of 10 females and 6 males aged 32 to 75 years Percutaneous needle biopsy of the kidney was performed in 12 cases, microscopy of the kidney at autopsy in 2 cases, percutaneous needle biopsy of the liver in one case and rectal biopsy in one case Renal involvement was not actually proved in the 2 last mentioned cases, but both patients had renal insufficiency

Fifteen of the 16 cases were considered as being secondary amyloidosis The predisposing diseases were rheumatoid arthritis in 8 cases, indistinct polyarthritis in one case, chronic infection of the urinary tract in 2 cases, pulmonary tuberculosis in one case, healed tuberculous lesions in the skeleton and lungs in one case, bronchiectasis in one case and pelveospondylitis ossificans (Bechterew's disease) in one case One case was considered as being primary amyloidosis

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Fig 1 Amyloidosis a) Nephroangiography 2 months after onset of renal insufficiency Large kidney with narrow branches of peripheral renal arteries No visible cortical vessels No visible demarcation between the renal cortex and the medulla b) Repeat nephroangiography 6 weeks later Substantial decrease in size of the kidney The cortex has become thin and the peripheral arterial branches tortuous

large at angiography had become small and shrunken 2 years later In 2 cases normal sized kidneys at angiography had become small at autopsy 6 months and 2 years later respectively In one case normal sized kidneys at angiography probably had the same size 4 months later when the patient died of circulatory insufficiency and was found to have only slightly advanced renal amyloidosis at microscopy This is the only case in the series that has been classified as primary amyloidosis

Renal blood vessels The diameter of the trunk of the renal artery has correlated well with the size of the kidney Fibromuscular dysplasia was demonstrated in one case In most cases the peripheral branches of the renal artery were narrower than usual (Fig 2) they were considered to be of normal width in 4 cases In small kidneys the peripheral arterial branches were tortuous in all cases and the calibre varied within a fairly wide range in several In 5 cases no cortical vessels could be seen, in 6 cases the visible vessels were sparse while in 5 cases their incidence was considered to be normal The renal vein filled normally in all cases and no thrombi could be demonstrated

The clinical findings comprised a wide range of variation at the time of the angiography The function of the kidneys varied markedly The serum creatinine values ranged between normal levels (the lowest 0 6 mg/100 ml) and pathologic values, the highest being 15 4 mg/100 ml Hypertension existed in one case only

The angiography was performed in varying phases of the disease The time from the onset of renal failure to angiography ranged from a few days to about two years In a few cases proteinuria had been demonstrated several years before renal failure was established In one case rectal amyloidosis was diagnosed one year before the onset of renal failure

Percutaneous transfemoral selective nephroangiography was performed on all patients, using a red Ödman-Ledin catheter (ID/OD 1 20/2 20 mm) The amount of contrast medium injected (Urografin 60 per cent) varied between 6 and 10 ml An AOT film changer was used with a standard programme 2 films/s during the first 4 s, followed by one film every other second for 8 s

Premedication varied due to the fact that the material covered a fairly long period of time The compounds administered were pethidine (1 ml) or Fortalgesic (30 mg) and 10–30 IU of Postacton (vasopressin) (LINDQVIST 1967) On theoretical grounds vasopressin may be expected to influence the appearance of the renal vessels However, LUNDSTRÖM (personal communication) has demonstrated that this is not the case with subcutaneous administration of such doses

The size of the kidneys, the diameter of the renal artery, the appearance of the intrarenal arteries, the thickness of the renal cortex and the demarcation between the cortex and the medulla, the circulation time and the contrast filling of the renal vein were assessed The kidney was considered to be of normal size when measuring 11 5 to 14 cm in length and 5 to 7 cm in width (MOELL 1961), and a renal artery diameter of 5 to 9 mm was regarded as normal (EDSMAN 1957) The values given by ABRAMS (1972) were used for the circulation time assessed as the arterial wash-out time The assessment of the width of the peripheral branches of the intrarenal arteries must necessarily be subjective but was based on personal experience from a large body of normal material

An attempt has been made to correlate the observations with the phase of the disease process and, in addition, with the degree of renal insufficiency, as expressed by the serum creatinine values

Results

Kidney size At the first examination the kidneys were considered to be large in 4 cases, of ordinary size in 5 cases and small in 4 cases, while in 3 cases there was one small and one large or normal-sized kidney Repeat angiography was performed in 2 cases In one of these a large kidney at the initial examination decreased considerably in size in 2 months (Fig 1) In the other patient small kidneys had become even smaller 6 weeks later In 4 cases a comparison could be made between the kidney size at angiography and at autopsy In one of these cases the kidneys which had been



Fig 4 Acute glomerulonephritis Nephro angiography in oliguric phase, 2 weeks after onset Large kidney with a thick cortex, poorly demarcated from the medulla Narrow intrarenal arteries with indistinct cortical vessels

evident that the angiographic parameters inherently related to the size of the kidney, e g the thickness of the cortex and the tortuosity of the renal blood vessels, were affected in a corresponding manner

In order to further elucidate the interrelation between the angiographic findings and the course of the disease, the material was classified in 2 groups, according to the *time* that had elapsed since the first signs of renal failure were observed The first group includes 8 patients in which renal insufficiency was diagnosed less than 4 months before angiography, the second group comprises patients with renal failure for 6 *months* or more The comparison revealed no substantial difference between the two groups The distribution was the same for kidney size, width of peripheral vessels and thickness of the renal cortex in both groups The only difference was a preponderance of poor cortico-medullary demarcation in the group with short histories, but also in this group one case exhibited distinct cortico-medullary demarcation

Correlation between the angiographic findings and the degree of renal insufficiency Two groups, 6 cases *in* one and 7 in the other were selected for this comparison, one comprising serum creatinine values of 0 6–1 7 mg/100 ml and the other values of 4 1–15 4 mg/100 ml The remaining 3 cases with serum creatinine levels of 2 0–2 6 mg/100 ml formed an intermediate group and would not have affected the comparison appreciably no matter which group they had been allotted to



Fg 2



Fig 3

Fig 2 Amylo dos s Nephroang ography one eek after onset of acute renal insuff c ency The k d ney is large and has a th ck cortex No v s ble cort co medullary demarcat on The intrarenal arter es narro v in all reg ons Cort cal vessels v s ble only locally

Fig 3 Amylo los s Nephroang ography after a brief per od of severe renal insuff c ency The co tex is th n and lacks v s ble vessels The cort co medullary demarcat on ind st nct Cons derab e var ation n calibre of the renal artery branches

The renal cortex was thin (5 mm or less) in 7 cases thick (8 mm or more) in 3 and normal in 6 cases but in one of these it varied within a fairly wide range The thickness of the cortex correlated well with the size of the kidney The demarcation between the cortex and the medulla varied and did not correlate with the kidney size It was distinct in 6 cases indistinct in 7 while no evident demarcation was found in 3 cases The course of the arcuate arteries indicated that the cortex was thick in 2 of the last mentioned cases and thin in the remaining case

Circulation time A satisfactory assessment of the arterial wash out time was possible in 11 cases In 10 of these it ranged within normal limits (1 5 to 3 s) while in the remaining case it was slightly prolonged The assessment was uncertain in 5 cases in 2 of these the wash out time may have been slightly prolonged

Correlation between the angiographic findings and the course of the d sease It has been stated that in time most of the amyloid kidneys diminished in size It is



Fig 4 Acute glomerulonephritis Nephroangiography in oliguric phase, 2 weeks after onset Large kidney with a thick cortex, poorly demarcated from the medulla Narrow intrarenal arteries with indistinct cortical vessels

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No difference in kidney size was found between cases with low and high creatinine levels but all cases with high creatinine values had narrow peripheral arteries The cortico-medullary demarcation was indistinct or not at all visible in the majority of these cases On the other hand, in the group with lower serum creatinine values some cases had normal peripheral renal arteries The thickness of the cortex was normal or increased in all cases in this group and the cortico-medullary demarcation was distinct in the majority of these cases

No regular difference existed between the angiographic appearances and the future course of the disease Thus, there were patients with small kidneys and thin renal cortex among those who lived a considerable time after the angiography, while some patients with large kidneys and thick cortex died a short time afterwards

Discussion

The angiographic appearances in the present series are similar to those reported by EKELUND & LINDHOLM Both series comprised large, normal sized and small kidneys As a rule, the peripheral renal arteries were narrow while the trunk was of normal width In some cases the subcortical arteries were irregular and incompletely filled The cortex was thin in many cases and many displayed an indistinct corticomedullary demarcation The renal vein filled in all cases

However, the present material permits a few additional considerations It seems quite obvious that, initially, the kidneys often are large in renal amyloidosis and then gradually decrease in size The time for this process varies in different cases This is evidenced by both the survival time and the angiographic appearances in relation to the length of the history The actual prognosis is always very poor, but it is difficult to assess in terms of time

The fact that the combination of chronic pyelonephritis and amyloidosis appears to be common renders the assessment of small amyloid kidneys considerably more *difficult It is probable that amyloidosis can develop as a sequel to pyelonephritis*, but pyelonephritis has been observed microscopically concurrently with amyloidosis also in cases where an adequate amyloidosis-inducing disease of another type has existed Thus 5 of the 7 patients with unilaterally or bilaterally small kidneys had microscopically confirmed chronic pyelonephritis These cases also had angiographic abnormalities consistent with those described by, among others, FRIEDENBERG et coll (1965) in chronic pyelonephritis In the 2 remaining cases with small kidneys no such abnormalities were demonstrated (Fig 3) None of the cases with large or normal sized kidneys had evident angiographic abnormalities suggesting pyelonephritis, whereas one of these cases was considered to exhibit modest changes of this type at microscopy

The course of the disease and the clinical picture in renal amyloidosis vary considerably Sometimes the onset is acute with oliguric renal insufficiency, *but in the majority of cases the disease takes a more prolonged course involving the nephrotic*

syndrome and progressive uraemia Therefore it would be of value if angiography could contribute to the differential diagnosis

The present series includes 2 cases with renal insufficiency of acute onset, and in one of these nephroangiography was performed in the oliguric phase (Fig 2) In this phase, in which the kidneys are large or normal sized, the angiographic appearance of the amyloidosis kidney is similar to that of acute glomerulonephritis (Fig 4) In both conditions as well as in other glomerular diseases the contrast accumulation in the renal cortex is poor However, some features may help the differentiation Thus the angiographic abnormalities in the group with acute renal insufficiency differ from those described by HOLLENBERG et coll (1968) in various conditions with acute oliguric renal failure, including acute glomerulonephritis, by virtue of, inter alia better filling of the peripheral vessels and normal or only slightly prolonged transit time The differentiation from cases of acute glomerulonephritis without acute renal failure is more difficult Narrow intrarenal arteries should suggest amyloidosis

The majority of the present cases presented clinically with a nephrotic syndrome In such cases with large or normal sized kidneys renal vein thrombosis and subacute-subchronic glomerulonephritis must be taken into consideration A normal or only slightly prolonged transit time renders thrombosis less likely in those cases where the renal vein cannot be appraised directly (HELLEKANT & KAUDE 1972)

The difficulties of differential diagnosis are further increased after the kidneys have diminished in size and the cortex has become progressively thinner In the majority of cases with small kidneys chronic pyelonephritis accompanied the amyloidosis In the final phase of renal amyloidosis it is probably virtually impossible to distinguish this condition from other advanced chronic renal diseases using conventional angiographic techniques

BARCLAY et coll emphasized renal vein thrombosis as a not uncommon complication in renal amyloidosis, but the fact that neither EKELUND & LINDHOLM nor the present authors observed renal vein thrombosis in a total of 22 cases, indicates that this occurs only to a limited extent, except as a terminal complication

On the basis of one of their own cases, EKELUND & LINDHOLM point out the risk of arteriovenous fistula after needle biopsy in amyloidosis A systematic follow-up of the patients of the present series was not made except in 2 cases In these no fistula could be demonstrated, nor did LUNDSTRÖM (1972) report a single case of amyloidosis in his large series of cases involving fistula after needle biopsy

Percutaneous needle biopsy is doubtless the most adequate method of arriving at a reliable diagnosis However, nephroangiography constitutes a valuable complement giving information on the development of the condition and on another concurrent renal disease Moreover, in cases of uraemia angiography is of great value for determining the suitable site for needle biopsy (JUNGHAGEN et coll 1968)

SUMMARY

The results of nephroangiography in 16 patients with microscopically confirmed amyloidosis are presented. In addition to the angiographic appearances, the course of renal amyloidosis is discussed in the light of repeated angiography and autopsy findings. The angiographic differential diagnosis is discussed, and the value of nephroangiography as a complement to other diagnostic methods is assessed.

ZUSAMMENFASSUNG

Die Ergebnisse der Nephroangiographie bei 16 Patienten mit mikroskopisch bestätigter Amyloidose werden vorgelegt. Zusätzlich zum angiographischen Bild wird der Verlauf der renalen Amyloidose auf der Basis von wiederholten Angiographien und den autoptischen Befunden diskutiert. Die angiographische Differentialdiagnose wird diskutiert und der Wert der Nephroangiographie als Komplement zu anderen diagnostischen Methoden festgestellt.

RÉSUMÉ

Les auteurs présentent les résultats de la néphroangiographie chez 16 malades présentant une amyloïdose confirmée microscopiquement. Outre les aspects angiographiques ils étudient l'évolution de l'amylose rénale à la lumière d'angiographies répétées et des résultats d'autopsie. Ils examinent le diagnostic différentiel angiographique et déterminent l'intérêt de la néphroangiographie comme complément d'autres méthodes diagnostiques.

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EPINEPHRINE IN THE ANGIOGRAPHIC EVALUATION OF EXPERIMENTAL KIDNEY TRAUMA

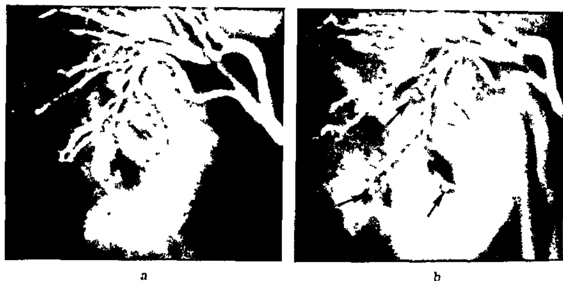
M L MOSS, C-H MENG and M ELKIN

Epinephrine injected into the renal artery has been investigated diagnostically in non traumatic conditions ABRAMS (1964) employed it in renal mass lesions to differentiate malignant and benign disease by the nature of the differential vascular responses to the drug Later, angiographic similarities have been noted between neoplasms and several benign conditions (CAPLAN et coll 1967)

Intra arterial *epinephrine* has been recommended for use in the diagnosis and treatment of traumatic conditions BOIJSEN et coll (1966) suggested possible therapeutic use in hepatic rupture to decrease bleeding in the preoperative period STEIN (1969) used epinephrine in 3 cases of traumatic laceration of the spleen and indicated that detail of lacerated vessels *was improved* The non traumatized intrasplenic arteries constricted normally, while those which were lacerated did not appear to respond Detail of lacerated vessels was enhanced without decrease in the leakage of contrast medium Dosages employed were 6, 10 and 20 μg in patients aged 10, 12 and 22 years respectively

DOPPMAN et coll (1967) employed intra aortic epinephrine (5 μg) and norepinephrine in monkeys which had been surgically traumatized six to ten days before the angiographic examination Incisions were made in the lower dorsal—upper lumbar area of the back and dissection was carried down to the laminae One lamina was

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a b

Fig. 1. a) Immediately following biopsy. No extravasation. b) 30 min following epinephrine. Extravasation from the 3 biopsy sites (→)

removed, exposing the cord, and in most animals a costotransversectomy was also performed. They found a dramatic increase in the filling of the wound vessels when compared to a non-vasoconstrictor control. Absent responsiveness of granulating wound vascularity to vasopressors results in shunting of blood through these vascular beds caused by sudden elevation of systemic pressure by the vasopressor infusion. Microscopy demonstrated typical granulation tissue with large, thin-walled, sinusoidal capillaries in a meshwork of proliferating fibroblasts and chronic inflammatory cells.

Angiographic findings immediately following percutaneous renal biopsy have been reported with the demonstration of active bleeding from the biopsy site (MENG & ELKIN 1971, LUNDSTRÖM 1972, KÖHLER & EDGREN 1974). Recently in one such patient the angiographic demonstration of post-biopsy bleeding was enhanced 60 seconds after the bolus injection of 2 µg of epinephrine, when compared to the examination before administration of the drug. This result seemed to be due to a diminished response of the traumatized vessel associated with the normal constriction of the other peripheral vessels. This clinical observation was similar to that of STEIN in respect to intrasplenic vessels.

Experiments in dogs to test the hypothesis that acutely traumatized vessels fail to respond normally to epinephrine are not reported. If this hypothesis were true, the use of epinephrine immediately before selective angiography could increase the angiographic delineation of sites of bleeding in the kidney.

Material and Methods

Nine mongrel dogs weighing an average of 17 kg were used. Under pentobarbital anesthesia, selective nephroangiography was performed by the transfemoral per-

Table

Effect of intra-arterial epinephrine on extravasation

Dog No	Post biopsy extravasation	Time after epinephrine-extravasation			
		45 s	2 min	5 min	30 min
*1	0	0	0	0	0
13	0	0	0	0	↑
9R	Yes	0	0	↓	↓
*5	Yes	0	↓	↓	—
10	Yes	0	↓	↓	0
6	Yes	↓	↓	0	0
9L	Yes	↓	↓	↓	↓
8	Yes	↓	↓	↓	—
7	Yes	→	→	→	↓
14	Yes	↓	↓	↓	↑

* Bolus injection of epinephrine
— Results at 30 min uncertain
0 No extravasation
→ Same amount of extravasation as on post biopsy film
↑ Increased amount of extravasation as compared to post biopsy film
↓ Decreased amount of extravasation as compared *to post biopsy film*

cutaneous technique A precurved red Kifa catheter was placed in the renal artery followed by an injection of 7 ml of Hypaque 50 % at 3 5 ml/s using a Cordis injector Films were exposed at the rate of one per second for 5 seconds with a Sanchez-Perez changer at 2 3 times direct magnification

Several percutaneous renal biopsies were performed immediately after angiography, utilizing the Franklin modification of the Vim-Silverman needle under direct fluoroscopy Renal tissue was obtained in all cases Within a few minutes after the biopsies a repeat selective angiography was done Injection and exposure technique were constant throughout the experiment Following the post-biopsy angiography, epinephrine was infused through the renal artery catheter in a concentration of 4 μg per ml of normal saline at *the rate of 1 5 ml/min* to give a *total infused* dose of 30 μg of epinephrine Seven of the dogs were infused as described and 2 were given a bolus of 10 μg epinephrine in 2 5 ml of normal saline In all 9 animals, films were exposed at 45 s, 2, 5 and 30 min following the termination of the epinephrine infusion or bolus, employing the same technique as utilized in the pre- and post-trauma examinations In one dog, both kidneys were examined

Results

Comparing the post epinephrine films with the post-trauma films, the magnitude of the vasoconstriction due to epinephrine was greatest at 45 s, with marked constric-



a b

Fig 2 a) Immediately following biopsy Bleeding from the 2 biopsy sites interlobar arteries having been traumatized b) 45 s following epinephrine Despite vasoconstriction still vigorous bleeding

tion of the main and intrarenal arteries The vasoconstrictive effect was less marked but still present at 2 min At 5 min the renal artery caliber had returned to the post biopsy diameter and in some experiments was even larger at 30 min Cortical ischemia was most evident at 45 s, after the cessation of epinephrine, reverting toward the post-biopsy state with a time sequence similar to that for renal artery size The increased vascular resistance due to epinephrine was reflected in reflux of contrast medium into the aorta as well as a significant delay in the emptying speed of the main renal artery and its branches A concomitant decrease in the rapidity of renal vein filling was also present during this period, as might be expected from the diminished renal blood flow

The extent of extravasation of contrast medium from the biopsy sites was quantitated visually on all films following biopsy (Table) In 2 dogs the post-biopsy film showed no extravasation, nor was any bleeding from the biopsy site observed on the post-epinephrine films of one of these animals In the other dog bleeding was evident 30 min after the end of the epinephrine infusion, possibly related to post-vasoconstriction hyperemia (ELKIN et coll 1971) (Fig 1)

In the remaining 8 kidneys (7 dogs) extravasation of contrast medium from the biopsy site was observed on the films exposed immediately after the biopsy In 6 of these animals (7 kidneys) bleeding was diminished or not demonstrable after the epinephrine In one animal the bleeding had diminished on the 45 s post-epinephrine film but increased on the 30 min film, possibly related to post-vasoconstriction hyperemia In one of the dogs the biopsy needle severed larger interlobar arteries resulting in such vigorous hemorrhage that the extravasation did not significantly respond to epinephrine, in this instance with constriction of more peripheral vessels

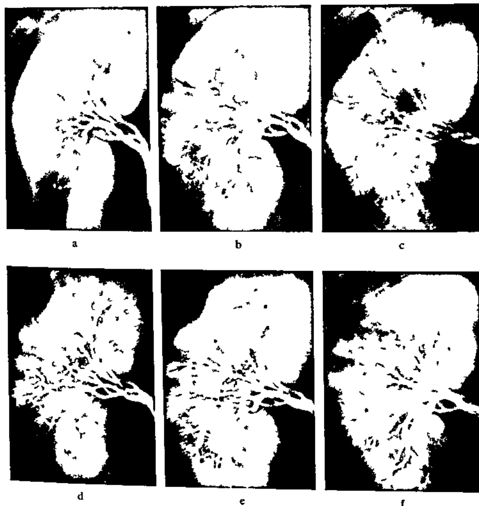


Fig. 3 a) Before biopsy [illegible]
Marked intrarenal [illegible]
intensity Vasoconst[illegible]

[illegible] min after epi[illegible]
greater than in (e) ([illegible] but still less than in (b)

due to the epinephrine, angiographic demonstration of the bleeding site was enhanced (Fig 2)

Thus most consistently the extravasation diminished immediately after epinephrine but then tended either to increase relative to that present at 45 s after epinephrine or to remain unchanged as the renal vessels returned to their pre-epinephrine state (Fig 3) The vessels feeding the bleeding site were demonstrated in some of the experiments,

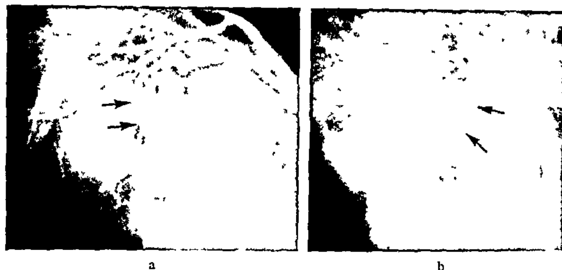


Fig 4 Immediately after biopsy Bleeding from the biopsy site the feeding traumatized vessel is visible (→) b) 45 s following epinephrine Still extravasation The intrarenal vessels are markedly constricted and also displaced by the hematoma The traumatized feeding vessel also participates in the vasoconstriction (→)

following epinephrine, the feeding vessels diminished in size but remained visible (Fig 4) In most dogs the bleeding sites were best demonstrated immediately post-biopsy or on the later films after epinephrine

Discussion

These experiments refute the hypothesis that acutely traumatized vessels do not constrict in response to epinephrine

In previous reports, attempts to explain the absence of vasoconstriction response to epinephrine in neoplasia, inflammation, and granulation tissue were focused upon the abnormality in the muscular development or muscular response of the vessels (ABRAMS 1964, CAPLAN et coll 1967) ALGIRE & CHALKLEY (1945) examined the development of vessels in wounds and transplanted tumors in mice using the transparent chamber technique The rapid ingrowth of vessels in wounds or transplanted tumors occurs between the sixth and ninth day By the ninth or tenth day, this vascularity may constitute up to 30 per cent of wound or tumor volume *In* wounds, however, these vessels begin to differentiate into venules and arterioles by the tenth day and for the first time a vasoconstrictive response to epinephrine can be demonstrated CAPLAN et coll hypothesized a refractoriness of precapillary sphincters to vasoconstrictors in renal inflammatory lesions This may account *in* part for the accumulation of contrast medium visible on the films

Traumatized vessels, on the other hand, differ from those present in neoplasia and healing wounds in that they possess normal musculature The present data indicate that trauma to vessels, namely laceration by the biopsy needle, *does not*

mhibit their constrictive response to epinephrine A generalized vasoconstriction with diminution in leakage of contrast medium occurs 45 s after the epinephrine As the epinephrine effect wears off, non traumatized and traumatized vessels return towards their normal appearances and in some instances there is evidence of a hyperemia If a clot has formed during the period of relative stasis with the early vasoconstriction, extravasation of contrast medium subsequently decreases or ceases Absence of clot formation results in increasing hemorrhage as the vasoconstriction diminishes Possibly in these instances, the dose of epinephrine has been such as to produce peripheral vasoconstriction and yet not produce adequate constriction of the bleeding vessel

We regret the untimely death of Dr Chien Hsing Meng soon after completion of the manuscript

Acknowledgements

Special appreciation is given to the photographic work of Milton Kurtz and the technical assistance of Louis Mendez

SUMMARY

Selective nephroangiography was performed in the dog following nercutaneous needle
to epineph-
A selective

ZUSAMMENFASSUNG

Selektive Nephroangiographie wurde bei Hunden nach einer perkutanen Nadelbiopsie vorgenommen um den Effekt von Epinephrin festzustellen Traumatisierte Gefasse reagierten normal gegenuber Epinephrin, oft mit einer gesteigerten Extravasation als der Effekt von Epinephrin aufhort Keine selektive Unfahigkeit der traumatisierten Gefasse sich zu kontrahieren wurde beobachtet

RÉSUMÉ

Les auteurs ont fait une nephroangiographie selective sur le chien apres biopsie percutanee à l'aiguille pour apprécier la rèponse à l adrenaline Les vaisseaux traumatisés repondent normalement à l adrénaline avec souvent une augmentation de l extravasation quand l effet de l adrénaline sur le vaisseau cesse Les auteurs n ont pas constate d incapacite sélective des vaisseaux traumatisés à se contracter

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COMPLICATIONS OF PERCUTANEOUS TRANSTHORACIC NEEDLE ASPIRATION BIOPSY

W N SINNER

Since LEYDEN as early as 1883 performed percutaneous lung puncture in order to diagnose microorganisms in pneumonia and MÉNETRIER in 1886 for the first time diagnosed a pulmonary carcinoma by transthoracic aspiration, the method became widely used during the end of the 19th and the beginning of the 20th century However the lack of adequate equipment and visual control led to major complications The enthusiasm for this method was also lessened since it was considered to involve risks for tumour cell spread and air embolism (OCHSNER & DEBAKEY 1939) In spite of technical improvement (SILVERMAN 1928, MARTIN & ELLIS 1934) and favourable results (SAPPINGTON & FAVORITE 1936, ROSEMOND et coll 1949, LAUBY et coll 1965) the method was not generally accepted for a long time Out of fear for complications, some authors suggested its limited use for relatively large, inoperable lesions near the pleura (WIKLUND 1951, DUTRA & GERACI 1954, GRUNZE 1955, PERTTALA 1959) Others (CRAVER & BINKLEY 1939) stated that needle biopsy should not be applied when bronchoscopy or lymph node biopsy could be performed and not until three cytologic sputum examinations had failed to give a positive diagnosis

However during the last decade, transthoracic percutaneous needle aspiration biopsy has been increasingly accepted as a standard method for the diagnosis of possibly malignant pulmonary lesions for four reasons (1) improved radiologic technique permitting direct control of the biopsy procedure by television fluoroscopy, (2) advances in and increased acceptance of, cytologic diagnosis, (3) application of

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Table 1

Complications of needle biopsy reported in the literature

Complication	Reference	Frequency	Treatment
Pneumothorax	Castelain et coll (1971)	0 %	None in most cases A few required aspiration of air (1 4 to 17 %) or chest tube drainage
	Lauby et coll (1965)	6 1 %	
	Weill et coll (1970)	15 %	
	Johnsson & Schnürer (1971)	16 9 %	
	Thornbury & Walls (1973)	27 %	
	Fontana et coll (1970)	57 %	
Local bleeding	Thornbury & Walls (1973)	5 %	
Hemoptysis	Castelain et coll (1971)	1 25 %	None Stopped in all cases within 30 minutes
	Lauby et coll (1965)	3 2 %	
	Jameson (1970)	6 0 %	
	Thornbury & Walls (1973)	7 0 %	
	Lalli et coll (1967)	10 0 %	
Implantation of malignant cells into the needle track	Dutra & Geraci (1954)	1 case	Biopsy performed with Vim Silverman needle
	Wolinsky & Lischner (1969)	1 case	Biopsy performed with Vim Silverman needle
Spread of tumour cells to the pleura	Berger et coll (1972)	2 cases	Pathologists differ in opinion on cytologic findings of pleural fluid
Air embolism	Jameson (1970)	0 02 %	
	Westcott (1973)	1 case	Patient died
Mortality	Adamson & Bates (1967)	1 case	Performed with Vim Silverman needle Autopsy revealed pulmonary haemorrhage
	Meyer et coll (1970)	1 case	Autopsy revealed pulmonary haemorrhage
	Lauby et coll (1965)	3 cases	Only 1 death directly attributed to the biopsy (untreated tension pneumothorax)
	Woolf (1954)	1 case	Death due to air embolism
	Westcott (1973)	1 case	Death due to air embolism (radiographically and pathologically confirmed)
	Johnsson & Schnürer (1971)	1 case	No cause of death found at autopsy

fine needles and (4) improved control of complications Since Nordenström introduced a technique employing these features into clinical use in 1961, the method has been revitalized

In a monograph, Dahlgren & Nordenström (1966) summarized the experience during the years 1963 and 1964 Additional impetus was given by the *introduction* of transjugular paraxiphoid and paravertebral approaches for mediastinal needle biopsy (Nordenström 1967a, b, 1972)

Table 2

Rate of complications in 2 726 cases

Complication	Frequency	Treatment
Pneumothorax	27.2%	Asymptomatic observation Symptomatic exsufflation, chest tube drainage
Local bleeding		
20–29 years	16.9%	None (resorption in 1–2 weeks)
Whole series	11%	
Hemoptysis		
Puncture near hilum	5%	None
Other regions	2%	
Implantation metastasis into needle track	1 case	Extirpation
Spread of tumour cells or infection to the pleura	0	
Air embolism	2 possible cases	Vasodilating drugs in one case, the other recovered spontaneously without sequelae
Other complications		
Bilateral pneumothorax	4 cases	Exsufflation
Pneumothorax with subcutaneous emphysema	7 cases	None
Mediastinal emphysema	2 cases	None
Bleeding	1 case	None
Mortality	0	

Experimental and clinical application of fine needle technique (FRANZEN 1968, DAHLGREN & NORDENSTRÖM) demonstrated that major complications are rare or entirely absent. The indications for transthoracic biopsy were therefore widened.

Material

The complications as reported in the literature are listed in Table 1. Using the technique of DAHLGREN & NORDENSTRÖM, LALLI et coll. (1967), WALLS et coll. (1970), CASTELAIN et coll. (1971), THORNBURY & WALLS (1973) and others reported no complications other than pneumothorax, hemoptysis and local bleeding, which rarely had to be treated. However, only comparatively small series have previously been analysed for complications.

Based on results from the major part of the personal series, the significance of percutaneous transthoracic biopsy in small peripheral and mostly asymptomatic pulmonary lesions with a diameter of less than 2 cm was previously reported (SINNER 1973). In 302 of 2 450 …
were cytologically classified

culosis 77, tuberculoma 69, hamartoma 30, bronchial adenoma 11, neurilemmoma 3, chondroma 2, Wegener's granulomatosis 2, aspergillosis 1, plasma cell granuloma 1), while 106 (36 %) yielded cytologic evidence of malignancy (primary bronchogenic carcinoma 58, solitary lung metastasis with extra-pulmonary primary tumour 30, cytologically undecided whether primary or secondary 18) The number and type of complications in small lesions did not differ significantly from those of larger lesions but a more detailed analysis of the complications was not made

Since the previous report the material has increased to 5 300 needle biopsies on 2 726 patients in 3 799 clinical visits This material is now evaluated with respect to factors influencing risks and complications in needle aspiration biopsy and how to define indications in order to get the maximum benefit out of this method with improved control of complications

Technical variations, which have to be distinguished from the method of DAHLGREN & NORDENSTRÖM, and which are not discussed in the present report, include (1) the use of the Vim-Silverman needle, the Jack needle or other large bore needles, (2) trephine biopsy using a high speed air drill, (3) open biopsy by thoracotomy

These and similar methods yield tissue specimens for microscopy rather than a cellular aspirate for cytologic analysis

Results

In 46 4 % of the total material there was cytologic evidence of malignancy, in 9 8 % of benign tumours or pseudotumours, in 7 4 % of granulomas of different nature, in 22 5 % of inflammatory lesions, non-specific or specific, and in 1 2 % of other lesions A cyst was punctured in 1 6 % In 9 3 % no cytologic diagnosis was possible

The result of the cytologic examination agreed well with the microscopic findings at operation or autopsy Compared to previous series (SINNER 1973) a relatively larger fraction of malignant lesions was found in the total material (36 % against 46 %) since the nature of small lung lesions is more difficult to assess than larger lesions, infiltrating or with metastases

The present report of the complete series (1961 to 1974) includes the complications previously reported on parts of the material (DAHLGREN & NORDENSTRÖM, SINNER 1973), they are listed in Table 2

Pneumothorax The incidence of pneumothorax in the total material related to the number of patients was 27 2 per cent and to hospital visits 18 0 per cent (Fig 1) The number of puncture procedures could vary from 1 to 5 per hospital visit on an outpatient basis, but was most often 2 As the number of the procedures was not always recorded the corresponding mean percentage of pneumothorax could not be established precisely However, from the cases where the number of punctures was known, a factor of 1 4 punctures per hospital visit could be calculated Using this figure, the frequency of pneumothorax related to the number of procedures in the total material can be extrapolated to 12 9 per cent (Fig 1) Most of these cases were asymptomatic

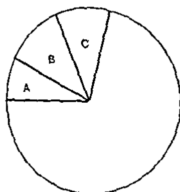


Fig. 1 Relative frequency of pneumothorax in 2 726 patients ABC in relation to total number of patients, 27 2 % AB in relation to hospital visits 18 % A in relation to number of biopsies 12 9 %

The patients were observed until the air had been completely resorbed The number of pneumothorax cases being symptomatic or requiring active treatment by simple exsufflation of air or by using a chest tube drainage was 7 7 per cent The factors influencing the incidence of pneumothorax are presented in Table 3 and Figs 6 and 7

Fig 2 illustrates the increasing rate of pneumothorax with age A statistically significant difference in the relative frequency between men and women (χ^2 test, $p < 0\ 001$) was demonstrated in the age groups 40 to 59 years

Fig 3 reveals that the frequency of pneumothorax is comparatively low in the group of lesions with a diameter of 2 6 to 3 5 cm Apparently it was easy to obtain satisfactory cytologic material of these lesions In larger lesions more difficulty may be encountered because of secondary abnormalities such as atelectasis, local emphysema, inflammatory lesions surrounding a tumour and central necrosis requiring several punctures to obtain representative cytologic material Statistical analysis using the χ^2 test (SNEDECOR) did not reveal any significant difference in the frequency of [illegible] the site of [illegible] different lo[illegible] lesions in the lobes of the lung ($p > 0\ 05$), except that pneumothorax was more frequent with increasing depth of the lesions (Fig 4) However, a significant difference was found between lung lobes and mediastinum ($p < 0\ 001$) and between mediastinum and pleura ($p < 0\ 005$)

The relative frequency of pneumothorax increased insignificantly with the outer diameter of the needle, from 20 6 in the 0 9 mm needle to 26 3 per cent in the 1 2 mm needle, while with the use of slightly larger needles with 1 4 to 1 6 mm outer diameter (including punch-needles where a core of tissue may be obtained) the frequency was about 25 per cent, these latter needles have been used mostly for firm pleural abnormalities (Fig 5) However, a statistically significant sharp rise in the incidence of pneumothorax was noted if the puncture was repeated a second time within two hours (χ^2 test, $p < 0\ 05$) With the 0 9 mm needle the relative frequency rose to 35 2

Table 3

Factors influencing the occurrence of pneumothorax

Factor	Frequency	Comments
Age		
0–19 years	16 6 %	
60–69 years	27 2 %	
<70 years	43 3 %	
Sex		
Male	29 7 %	Fig 2
Female	21 3 %	
Location		
Different lung lobes	No significant difference	
Continuous with pleura	Less	
Size, larger lesions (2 6–3 5 cm in diameter)	Less than smaller lesions	Fig 3
Depth of lesion		
0 1–1 9 cm	9 1 %	Figs 4, 8
4 0–4 9 cm	35 7 %	
11 9 cm	48 4 %	
Outer diameter of needle		Fig 5
0 9 mm	20 6 %	2 punctures 35 2 %, 3 punctures 42 9 %
1 2 mm	26 3 %	2 punctures 45 5 %
1 4–1 6 mm	25 0 %	Mostly used for firm pleural lesions
Cytology		
Group 1	29 2 %	Includes malignant tumours (49 2 %, primary 39 0, secondary 7 4, probable 2 8)
Group 2	22 1 %	Includes benign tumours, pseudotumours, cysts (50 8 %)
Group 3	30 8 %	Includes inflammatory or non-tumorous lesions
Influence of special conditions or disease		
Emphysema		
None	16 9 %	
Moderate	47 9 %	
Marked	66 6 %	
Fibrosis and collagenosis	5 of 9 cases	
Tuberculosis	Not increased as compared to total material	
Pneumoconiosis	Insufficient data	
Obesity	No relationship found in 531 patients	
Experience of operator		
<20 procedures	44 5 %/20 procedures	
21–80 procedures	20 %/20 procedures	
>80 procedures	15 %/20 procedures	

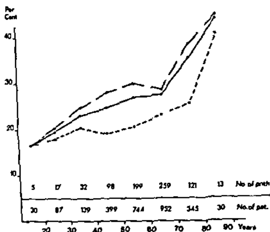


Fig 2 Frequency of pneumothorax in relation to age groups and sex (—— all patients —— men – – women)

per cent at the second and 42 9 per cent at the third puncture With the 1 0 mm needle there was a relative frequency of 45 5 per cent of pneumothorax after the second puncture (Fig 5)

In 1 264 of the 2 726 patients (46 6 %) cytology demonstrated malignancy Of these 1 064 (39 0 %) were classified as primary and 200 (7 4 %) as secondary malignant lesions In 75 of the total material (2 8 %) the cytologic diagnosis was a possibly malignant lesion and in 1 387 (50 8 %) the lesion was benign

Up to the age of 40 to 49 years, the frequency of pneumothorax did not differ between the various lesions After 50 years a somewhat larger relative frequency existed in group III (inflammatory or non tumorous lesions) with a mean total value of 30 8 per cent, and group I (malignant tumours) with 29 2 per cent compared to group II (benign tumours, pseudotumours and cysts) with 22 1 per cent The reason for this may be that patients with clinical or radiologic evidence of malignant or inflammatory lesions were punctured more often than those with benign lesions

Post puncture pneumothorax was strongly correlated to the presence of emphysema (Table 3) A qualitative diagnosis of the idiopathic diffuse types of emphysema (centrilobular or lobular) may usually be made by suitable radiologic examinations with films of high resolution (NORDENSTRÖM & KUMAZAKI 1974) As the results of lung function tests were available only in a limited number of the patients, radiologic evidence of emphysema was used in the present series The cases were divided into 3 different groups (Table 3)

In old pulmonary tuberculosis with fibrosis often a compensatory emphysema is present In 50 such cases no increased tendency for pneumothorax could be found, possibly because the effect of the emphysema was balanced by adhesions protecting the patient from a pneumothorax

Local pulmonary bleeding with a mean incidence of 11 per cent, seems to be of no significance as no patient required treatment In all the cases the bleeding was re-



Fig 3 Frequency of pneumothorax in relation to size of lesion (531 patients, 740 hospital visits) The lesion was measured in several projections, a mean diameter was calculated for every case Cases with irregular borders or diffuse lesions were excluded

sorbed completely after a few days up to 1 to 2 weeks Incidental puncture of vessels such as the pulmonary artery, the thoracic aorta, tumour-like aneurysms of the thoracic aorta and arteriovenous aneurysms was occasionally recorded, as well as incidental puncture of other organs like the liver (with liver cells as cytologic evidence in one case) without any symptoms or need for measures The innocuity of fine needle biopsies, even if taking an undue course and hitting vital organs, has also been observed by other authors using the same technique (LALLI et coll)

Nevertheless, such incidents can be avoided with careful planning of the puncture and increasing experience

Hemoptysis The incidence of hemoptysis was about 5 per cent in central lesions but only about 2 per cent in peripheral lesions In no case was hemoptysis a major complication, and it never required special management However, in one case a comparatively large hemoptysis prompted interruption of the procedure The hemoptysis stopped spontaneously and a biopsy could later be performed

Implantation of malignant cells into the needle track In the literature, no report of implantation metastasis after use of fine needles (18 to 22 gauge) has been found Although even in relatively large series where fine needle technique was used (ROSEMOND et coll , LAUBY et coll , DAHLGREN & NORDENSTRÖM) no evidence of metastasis emerged, the theoretical possibility of spread of tumour by implantation could not be excluded

In one case in the present material an implantation metastasis is assumed to have occurred (SINNER & ZAJICEK 1976)

Spread of tumour cells or infection to the pleura In 4 patients increased fluid in the pleura or interlobar spaces was observed Massive bleeding was suggested in one patient but thoracotomy yielded only pleural fluid No tumour cells were found in repeated samples

The incidence of inflammatory complications is low Empyema developed later on in two cases After puncture of an abscess a third patient developed a new lesion near

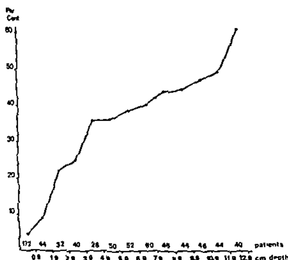


Fig 4 Frequency of pneumothorax in relation to depth of lesion (698 patients, 980 visits) The distance from the visceral pleura at the puncture site to the surface of the punctured lesion was measured and corrected for magnification The distance from the surface of the skin to the surface of the pleura was also measured

the primary one, close to the track of the needle In another 62 year-old man a pneumothorax occurred after puncture which had to be exsufflated, infection of the thoracic wall at the site of the exsufflation needle later developed In no other case evidence of local or generalized flare up of a non specific or tuberculous inflammation occurred

Air embolism is a rare, potentially life threatening complication No certain incidence occurred in the present series but in 2 cases air embolism may have been present

Bilateral pneumothorax Only one lung should be punctured at the same visit (SINNER 1975) In a 54-year-old man the wrong side was punctured by mistake, the other lung was also punctured on the same occasion, which resulted in bilateral pneumothorax In two further patients with bilateral lung lesions, both lungs were punctured which led to bilateral pneumothorax In a fourth patient bilateral pneumothorax occurred following a single puncture close to the mid line, probably because of the presence of a lung hernia

Pneumothorax with subcutaneous emphysema In 7 cases moderate to marked subcutaneous emphysema accompanied a large pneumothorax No supplementary treatment was required

Mediastinal emphysema occurred in 2 cases No treatment was necessary

Bleeding in the chest wall A hematoma in the thoracic wall caused by puncture of the intercostal artery occurred in one patient No treatment was required

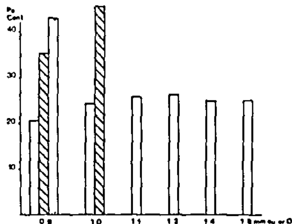


Fig 5

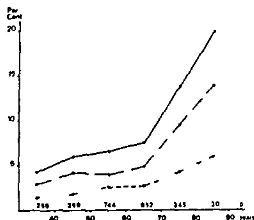


Fig 6

Fig 5 Frequency of pneumothorax in relation to the outer diameter of the needle and one or two repunctures related to number of patients [ ] first [ ] second [///] third biopsy

Fig 6 Relative frequency in different age groups of pneumothorax requiring treatment in per cent of the entire material —— pneumothorax in relation to all treatments pneumothorax re quiring exsufflation -- pneumothorax requiring chest tube drainage

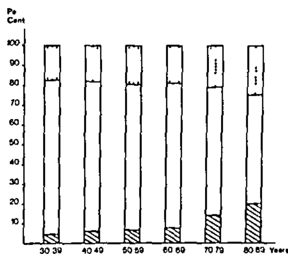


Fig 7

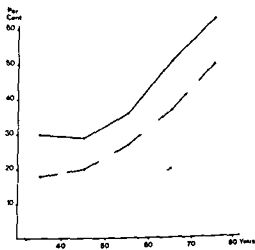


Fig 8

Fig 7 Relation of asymptomatic and untreated pneumothorax ([ ]) to pneumothorax requiring treatment ([///]) in different age groups

Fig 8 Correlation pneumothorax in depth — — lesio depth

' lesion) and relative frequency of
ons 2 cm diameter and > 12 cm
ons 2 cm d ameter and < 12 cm

Mortality In this series there was no death which could be attributed to the method In a 70 year old man with a previous history of myocardial infarction there was evidence of an acute myocardial infarction when the patient after a complication free procedure was under transportation back to the ward he improved spontaneously

An elderly man with emphysema was subjected to biopsy, performed with the same technique elsewhere and consequently not part of the present series This patient

probably developed an unrecognized tension pneumothorax and died untreated This mimicks a case reported by LAUBY et coll, both seem to have been potentially preventable deaths

Thus, it seems that using the present fine needle technique with facilities available for treatment of complications mortality for all practical purposes should be nil

Discussion

The incidence of pneumothorax depends on the condition of the patient and on the technique used but also on the extent with which complications are searched for This may partly explain the wide range of post puncture pneumothorax in other reports In the present series all cases of pneumothorax were included, even those with only 1 to 2 mm of air apically in asymptomatic pneumothorax, or those with pneumothorax not visible immediately after the procedure, but present from several hours up to several days later

Cases with paraxiphoid, transjugular and paravertebral approach were not included (JEREB & SINNER 1973) as they require other techniques (introduced by NORDENSTROM 1967, 1972) The incidence of pneumothorax in such cases for all practical purposes should be nil, as normally the pleura is not punctured

Local bleeding occurred in 11 per cent but was of no clinical importance and in no case required any measures Hemoptysis occurred in about 5 per cent of the centrally situated lesions but rarely in the peripheral ones (2 per cent of total material)

Implantation of malignant cells into the needle track, spread of tumour cells to the pleura, spread of infection and air embolism have been arguments against the use of transthoracic biopsy as a routine diagnostic procedure Previous reports, based on altogether several thousands of procedures have shown these complications to be very rare Only 2 instances of needle track implantation have been reported, both after use of large bore needles Spread of infection also seems to be very rare and can be controlled by modern chemotherapy

Air embolism is a rare, although life threatening possibility, certain precautions should therefore be taken

Mortality, apparently very rare, should be avoidable if the present technique with fine needles is used properly and if facilities are available for the immediate treatment of complications especially symptomatic pneumothorax The present review of complications shows that three main problems may be distinguished

Pneumothorax is the most frequent and practically most important complication of needle biopsy As was shown in the foregoing age and sex, the size and depth of the lesions repunctures, special conditions and diseases, and last but not least experience of the operator influence the relative frequency and the degree of pneumothorax Awareness of these factors is of practical significance as later developing major complications with potential mortality, like tension pneumothorax, must be recognized in time and treated adequately

Implantation of tumour cells into the needle track seems to be a rare possibility (about 0 04 per cent)

In a recently published survey (SINNER 1973) of a major part of the present material the author analysed 106 operated patients with peripherally situated malignant lung lesions under 2 cm of real size, all diagnosed at an early stage The 5-year survival rate was 42 per cent for primary carcinoma and 32 per cent for solitary metastases of extrapulmonary tumours These results, which may well be compared with those of other reports, indicate that if spread of tumour cells exists, it is of minor importance and more than out-weighed by the advantages of early diagnosis and treatment of pulmonary malignant lesions MOORE et coll (1967) and ROBERTS et coll (1962) have pointed out that diagnostic and therapeutic procedures favour tumour cell spread Many authors have stated that malignant tumours, not only in the lungs, continuously disseminate tumour cells into the blood stream (SANDBERG et coll 1959, SINNER & SCHINZ 1964, SINNER 1963, and others) ROBERTS et coll found tumour cells in the blood in 108 patients with different tumour localizations in 48 per cent before, during and after operation and in 17 per cent only during operation They also found a significant increase of tumour cells in the blood after manipulations like rectal or gynaecologic examinations, intensive washing of the tumour area (in mammary tumours) and in diagnostic procedures like bone biopsy and curettage of the uterus However, ENGELL (1955) found malignant cells in blood samples from the tumour area about as often in patients surviving without evidence of recurrence or metastases as in those who developed recurrence or metastases and concluded that this test provided no significant information of prognosis

It may be concluded that in most cases malignant cells entering the blood stream are destroyed Recently ENGZELL et coll (1971) investigated the possibility of spread of tumour cells in connection with aspiration biopsy of lymph node metastasis in animal experiments (18 gauge needles) and in a clinical series of 157 patients with pleomorphic adenoma of the salivary glands and of 469 patients with prostatic carcinoma, all diagnosed by fine needle (22 gauge) biopsy No evidence emerged of local extension of tumour growth or appearance of metastases attributable to the biopsy Thus, there would seem to be no ground for fear of tumour spread following transthoracic biopsy, resulting in transformation of an early operable lesion into an inoperable or incurable state

Air embolism In the past air embolism was a well recognised complication of thoracocentesis and therapeutic pneumothorax Apart from cases in which air is directly introduced into the lung, air embolism is theoretically possible (1) if the tip of the needle is positioned in a pulmonary vein and (with removed mandrin) the atmospheric pressure exceeds the pulmonary venous pressure as might occur under a rapid inspiration, and (2) if an open communication has become established between a bronchus or air space of the lung, in a rigid lung air might be blown into the vein during a coughing episode

WESTCOTT (1973) recently described one such case of air embolism with radiographic and pathologic documentation As this case seems to be the only one strictly documented, air embolism appears to be an extremely rare complication in transthoracic biopsy In some other cases there is circumstantial clinical evidence rather than pathologic proof Based on the present material, the relative risk per patient is then estimated to be about 0 07 per cent However, the incidence may be further reduced or avoided if precautions are taken to warrant that the intrathoracic pressure will exceed the atmospheric pressure Positive pressure breathing and a Valsalva manoeuver seem not to be practical measures It is mandatory that patients should not be examined in a half recumbent or upright position The open needle should not be left for any length of time in situ if venous blood is obtained After the needle has reached its definite position the syringe has to be connected without delay after the stylet has been removed Since a sudden inspiration after an apnoea or a coughing episode might favour that the atmospheric pressure exceeds the pulmonary venous pressure, the patient should breathe normally during the procedure and only thin needles should be used It may be concluded that few complications occur following needle aspiration biopsy if the procedure is carefully planned and performed on strict indication

SUMMARY

After 5 300 percutaneous transthoracic needle aspiration biopsy procedures in 2 726 patients pneumothorax occurred in 27 2 per cent of the patients Only 7 7 per cent required exsufflation or drainage The factors influencing the relative frequency and the severity of pneumothorax are discussed Bleeding around the punctured lesions was found in 11 per cent,
... vidence of
... of tumour
... embolism
... occurred

ZUSAMMENFASSUNG

Bei 5 300 perkutanen transthorakalen Nadelaspirationsbiopsien an 2 726 Patienten trat bei 27,2% der Patienten ein Pneumothorax auf Nur 7,7% benötigten eine Absaugung der Luft oder eine Drainagebehandlung Es werden die Faktoren, die die relative Frequenz und den Schweregrad des ...
Punktionswu ...
klinische Be ...
funden Die ... Bedeutung der Streuung von Tumorzellen und Infektionen durch den Stichkanal werden diskutiert Es traten keine Luftembolien oder Todesfälle auf

RÉSUMÉ

Après 5 300 biopsies transthoraciques percutanées à l aiguille avec aspiration chez 2 726 malades un pneumothorax est apparu dans 27,2 pour cent des cas L'exsufflation ou le

drainage n ont été nécessaires que dans 7,7 pour cent L auteur examine les facteurs qui influent sur la fréquence relative et la gravité des pneumothorax Il y a eu un hématome autour des lésions ponctionnées dans 11 pour cent des cas et une hémoptysie dans deux pour cent mais elles n ont pas eu d importance clinique Dans un cas il y a eu des signes de greffe tumorale le long du trajet de l aiguille L auteur examine l importance théorique et pratique de la dissémination de cellules tumorales et d infection par le trajet de l aiguille Il n y a pas eu d embolie gazeuse ni de mort

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PNEUMOCYSTOGRAPHY OF BENIGN AND MALIGNANT INTRACYSTIC GROWTHS OF THE FEMALE BREAST

L TABÁR and Z PENTEK

Statistical observations have shown that about one in every 10 women develops mammary cysts before the menopause, indicating that cystic disease is the most common lesion of the breast (HERBERT & OUIMET OLIVA 1972) Cysts have been differentiated by INGLEBY & GERSHON COHEN (1960) into apocrine, secretory or papillary on a pathogenetic basis They stated that in the case of papillary cysts the secretion and bleeding of the intraductal papilloma dilate the duct and cause cyst formation In accordance with HAAGENSEN (1956) they assume that the majority of these tumours are benign and remain so, while malignant papillomas have a malignant character from the beginning

Diagnostic procedures aim to give the most accurate possible diagnosis before surgery By physical examination alone it is impossible to establish the diagnosis of an intracystic papilloma or malignancy Soft tissue radiography of the breast may indicate the true nature of the lesion only in certain rare cases, with the help of secondary signs of malignancy such as the 'comet tail sign', calcific deposits in the intracystic carcinoma, etc

The value of pneumocystography lies in the fact that it is easy to perform and reliably detects the smallest intracystic growth and thus provides a good means of diagnosing these unusual tumours preoperatively, which is not possible by any other method at present The conclusion is, therefore, that if radiology and clinical

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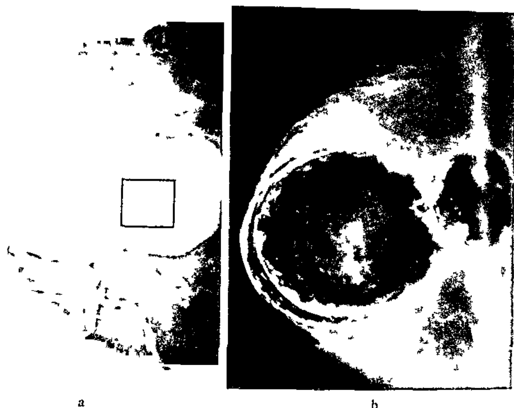


Fig 1 a) Large tumour Calcific deposits in the tumour b) Pneumocystography Numerous broad based intracystic papillary growths

findings suggest the presence of a cyst in the breast, needle aspiration and pneumo cystography should be performed

Technique of examination After the fluid has been aspirated from the cyst it is filled with air through the same needle and films are exposed of the breast in two planes All fluid should be removed and the amount of air injected should not exceed three quarters of the amount of the aspirated fluid since it expands at body temperature Local anaesthesia is used and care is taken to maintain aseptic conditions It is recommended that the aspirated fluid be examined by a cytologist A positive cytology may be of great help but a negative result does not exclude the presence of an intracystic malignancy

Although the size of the cyst can be determined from mammographic films, it is easier and more accurate to calculate it from the quantity of the withdrawn fluid

Material In 132 pneumocystographies performed on 103 patients solitary cysts were found in 41 and multiple cysts in 62 patients In addition, 20 cases of intracystic tumour were diagnosed preoperatively, composed of 11 intracystic carcinomas and 9 benign intracystic growths, and these 20 cases provide the basis of this report Some typical cases are presented in detail

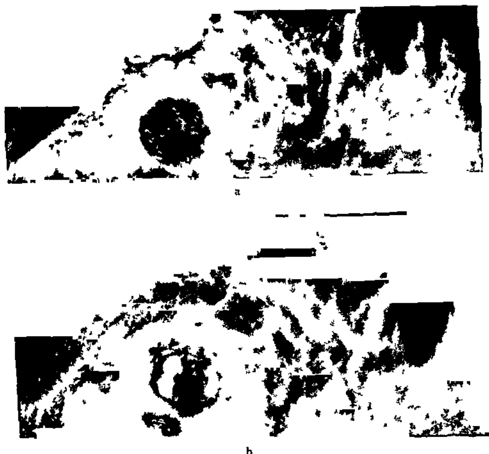


Fig. 2 a) Cyst measuring 2 cm 2 cm b) Pneumocystography A broad based tumour nearly fill ng the whole cyst

Case reports

Case 1 A 67 year-old female with a slowly growing tumour in her right breast since 5 years Physical examination a large, oval mobile tumour No skin retraction or enlarged axillary lymph nodes could be found The clinical diagnosis was benign tumour possibly a homogeneo is cyst [illegible]
st
w
a
b
c

Case 2 A 41 year-old female with a mobile tumour in the lower inner quadrant of her left breast Physical examination benign tumour just under the skin without retraction

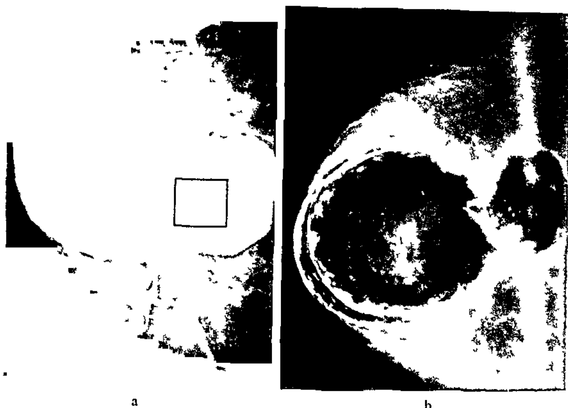


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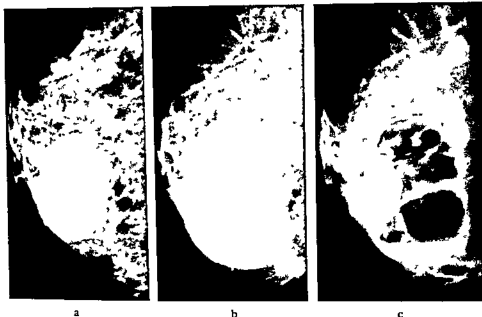


Fig. 4 a) Mammary radiography A 3 5 cm × 3 5 cm cyst in the lower half of the breast b) One month later The cyst is doubled in size c) Pneumocystography A 1 5 cm thick anterior wall of the cyst (caused by tumour tissue)

the discharging duct filled the cyst which indicated that the fluid in the cyst was produced by the papilloma and after trauma discharged through the duct (Fig 5 c) Microscopy benign papilloma

Discussion

Breast cysts are rarely observed in young women, they occur most frequently in the menopause The mean age of the patients reported by ROSEMOND et coll (1969) was 40 years, ranging from 15 to 64 years In the present material the average age was found to be 46 5 years, ranging from 31 to 77 years

As with other breast tumours, cysts are usually first detected by the patients themselves and by this time cysts have generally reached a diameter of several centimeters They are usually painless, although occasionally, e g before menses or when compressed, they cause pain Some patients complain of tension and sharp pain in a certain area of the breast and the skin may go red over a large palpable tumour. These symptoms disappear under antiinflammatory therapy and the size of the tumour decreases The radiologic appearances of cysts are well-known (EGAN 1964, GERSHON-COHEN 1970, HOEFFKEN & HINTZEN 1970, HOEFFKEN & LÁNYI 1973, TABÁR et coll 1973) Intracystic tumours, whether benign or malignant, have no typical features which provide a reliable basis for their detection during clinical examination, unless the cyst suddenly becomes considerably enlarged (HAAGE &

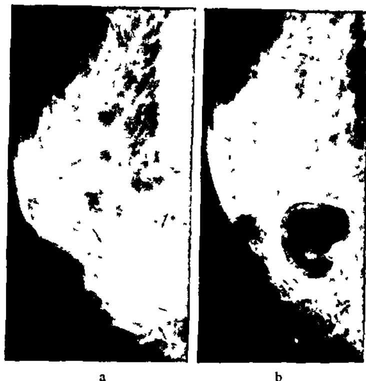


Fig 3 a) Mammary radiography Cyst b) Pneumocystography Small broad-based intracystic tumour

Mammary radiography (Fig 2 a) a 2 cm × 2 cm cyst Pneumocystography (Fig 2 b), after aspirating 4 ml straw-coloured fluid a broad-based tumour nearly filling the whole cyst Cytology no malignant cells Microscopy intracystic papillary carcinoma

Case 3 A 49-year-old female with a trauma to her right breast 3 months before admission Two months later, she experienced a dull pain and felt a tumour in the breast Physical examination in the lower, outer quadrant a tumour with a diameter of 4 cm, possibly benign Mammary radiography (Fig 3 a) a cyst measuring 4 cm 3 cm Eight ml turbid yellowish fluid was obtained by puncture and submitted to cytology degenerated epithelial cells, leucocytes and undamaged papillary cell groups Pneumocystography (Fig 3 b) broad-based intracystic tumour suggestive of malignancy Microscopy carcinoma

Case 4 A 34-year-old female with a tumour in her right breast for 2 months Physical examination a 5 cm tumour in the lower, outer quadrant of the breast, possibly benign Mammary radiography (Fig 4 a) a cyst measuring 3 5 cm 3 5 cm As she was not operated upon immediately a further mammary radiography (Fig 4 b) a month later revealed that the size of the tumour had doubled Cytology 14 ml straw-coloured fluid obtained by puncture revealed blood cells, lymphocytes and numerous malignant cells Pneumocystography (Fig 4 c) a cyst divided into compartments with a 1 5 cm thick anterior wall and wavy inner contour, probably malignant Microscopy solid carcinoma, partly anaplastic

Case 5. A 49-year-old female discovered a small tumour just beneath the left areola mammae On injuring her breast 2 weeks after discovering the tumour she observed a serous nipple discharge Physical examination a seemingly benign tumour, possibly fibroadenoma or cyst Mammary radiography (Fig 5 a) an oval-shaped tumour Pneumocystography (Fig 5 b) broad-based intracystic growth with papillary surface The attenuation of the tumour was slightly less than that of the fluid in the cyst Contrast medium injected through



Fig 4 a) Mammary radiography A 3 5 cm × 3 5 cm cyst in the lower half of the breast b) One month later The cyst is doubled in size c) Pneumocystography A 1 5 cm thick anterior wall of the cyst (caused by tumour tissue)

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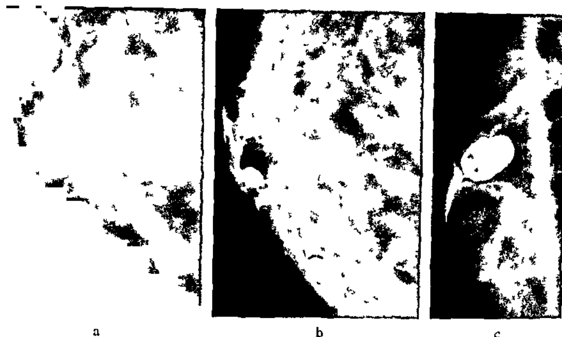


Fig 5 a) A small oval shaped tumour just beneath the areola b) Pneumocystography A broad based intracystic growth with papillary surface c) Contrast medium injected through the discharging duct passed into the cyst The filling defect is caused by an intracystic papilloma

FISCHEDIK 1964, ROSEMOND et coll 1969) The relatively young age of the 11 patients with intracystic carcinoma was remarkable, the youngest being 34, two others 41, three others 48, 49 and 52 years, respectively The remainder were older and the average age was 51 years The data related to the size of these cysts confirm the observation by ROSEMOND et coll that the 'size has no relationship to malignant change' The amount of fluid aspirated from the smallest carcinoma containing cyst was 8 ml, in three others it was 14 ml, while the largest cyst contained 150 ml fluid The fluid gained at puncture was straw-coloured, bloody or dark-brown with debris In all the 11 patients with intracystic malignancy the clinical diagnosis was a benign tumour Although mammary radiography provided some suggestion of malignancy in 4 patients, on the basis of the 'comet-tail sign', blurred cyst contours and calcific deposits, a firm diagnosis could only be obtained with pneumocystography

Cytology of the aspirated fluid led to the detection of malignant cells in only 2 cases

No explanation for the large number of intracystic tumours in the present material has been found HOEFFKEN & LÁNYI consider them rare HAAGENSEN reported a proportion of 0 2 per cent of all malignant breast tumours, GATCHELL et coll (1958) found 0 5 per cent, in the present material the incidence was 2 18 per cent (11 intracystic among 505 malignant breast tumours)

The mean age of the 9 patients with benign intracystic papillomas diagnosed by pneumocystography was 41 years (between 30 and 49 years) The cysts with papillomas



Fig 6 Pneumocystography of benign intracystic papillomas

were relatively small, containing 3 to 9 ml fluid, due to their localisation, mostly behind the areola, they were palpable despite their smallness Three patients complained not only of a palpable tumour but also of a bloody nipple discharge The intraductal papilloma appears to develop just behind the nipple and produces a serous fluid which enlarges the duct, thus producing a cyst (intracystic papilloma) After reaching a certain size or under the influence of external pressure, some of the serous or bloody fluid from the cyst empties through the duct, thus limiting the size of the cyst

Pneumocystography demonstrates clearly if the surface of the cyst is smooth or contains a growth It can be performed on an out patient basis and only requires local anaesthesia and asepsis Complications are rare Scarring of the breast is not caused even after repeated examinations Cysts filled with air seldom produce fluid again and the cyst gradually disappears, this has led to treatment by aspiration This treatment may be used only if pneumocystography is performed to exclude the presence of an intracystic tumour, and if cytology of the aspirated fluid reveals no tumour cells

Soft tissue radiography of the female breast, cytology and pneumocystography together provide accurate and reliable means of diagnosing cysts and intracystic tumours at an early stage and thus increase the prospects of successful therapy

Acknowledgement

The authors are grateful to Dr István Kádas Department of Pathology, Baranya County Hospital Pecs and to Dr József Balogh, Department of Pathology, Balassa J County Hospital Szekszard, for the microscopy

SUMMARY

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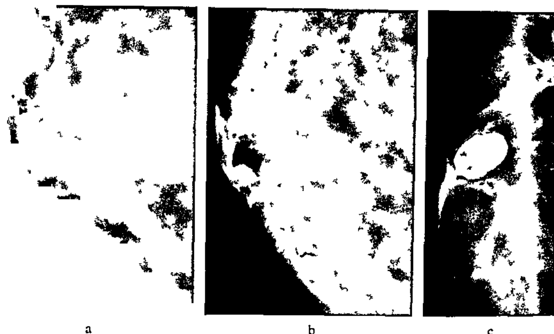


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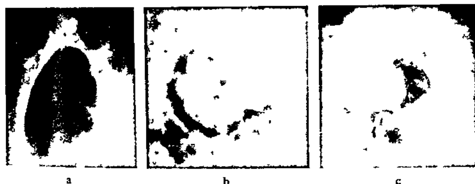


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generally considered to be a rarity The method is described and details about the clinical and radiologic appearances of both benign and malignant intracystic tumours are given The importance and advantages of the method are emphasized

ZUSAMMENFASSUNG

Die Pneumozystographie ergab die präoperative Diagnose von 20 intrazystischen Brusttumoren 9 benigne intrazystische Papillomen und 11 intrazystische Karzinomen die allgemein als Rarität betrachtet werden Die Methode wird beschrieben und Einzelheiten des klinischen und röntgenologischen Bildes für sowohl benigne als auch maligne intrazystische Tumoren gegeben Die Bedeutung und Vorteile der Methode werden hervorgehoben

RÉSUMÉ

La pneumokystographie a établi le diagnostic pré opératoire de 20 tumeurs intrakystiques du sein, dont 9 papillomes intrakystiques bénins et 11 cas de carcinome intrakystique qui est généralement considéré comme une rareté Les auteurs décrivent cette méthode et donnent des détails sur les aspects cliniques et radiologiques des tumeurs intrakystiques bénignes et malignes Ils soulignent l'intérêt et les avantages de cette méthode

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FROM THE DEPARTMENTS OF PAEDIATRICS (DIRECTOR B LINDQUIST), RADIATION PHYSICS (DIRECTOR K LIDÉN) AND ANATOMY (DIRECTOR C-H HJORTSJÖ), UNIVERSITY HOSPITAL, S-221 85 LUND, SWEDEN

BONE GROWTH IN THE RABBIT AFTER IRRADIATION

A S ARONSON, MONICA GUSTAFSSON and G SELVIK

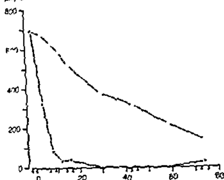
The stunting effect of high local radiation doses on the growing bone has been convincingly and repeatedly reported both in animals (PERTHES 1903, HINKEL 1942) and in man (for review, see RUBIN & CASARETT 1968, PROBERT & PARKER 1975) The effect of lower doses, below 1 Gy (100 rad), have not been evaluated, neither experimentally nor clinically From extrapolation of the graded effects of higher doses, this low range has been considered safe and the minimum stunting dose has been estimated to be well above 1 Gy (ICRP No 14, 1969, RAUSCH et coll 1964)

Small growth disturbances on a subclinical level, undetectable by conventional bone length measurements, still cannot be excluded and have in fact been discussed (MOSS 1959, RUBIN & CASARETT 1968) The introduction of a new high-sensitive roentgen spectrophotogrammetric method for the determination of the bone length growth makes it possible to record otherwise undetectable small disturbances (ARONSON et coll 1977) This report presents the effect of 0 1 Gy to the tibia of the rabbit as measured with the stereophotogrammetric method

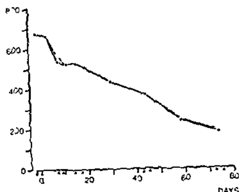
Material and Method

One litter of 8 rabbits was used during their 27th to 132nd day of life They were kept institutionalized together with their mother

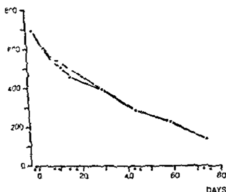
Submitted for publication 3 March 1976



a



b



c

The tibial *bone growth* was measured bilaterally with roentgen stereophotogrammetry (SELVIK 1974, ARONSON et coll 1977) To increase the accuracy of these measurements, the legs had been furnished with intraosseous markers Tantalum balls 0 50 mm in diameter were deposited in the two epiphyseal ends of the left and right tibial bones (ARONSON et coll 1974, ARONSON & JONSSON 1977) At each measuring instance, the rabbit was placed in a calibration cage, and the lower extremities were simultaneously exposed with two roentgen tubes The double image of the set-up was recorded on a Kodak D7 fine grain film The film was evaluated in an autograph (A8 Wild, Heerbrugg, Switzerland) and the spatial locations of bone markers in relation to markers in the test cage were computed, mathematical analysis being based on perspective transformation (HALLERT 1970, SELVIK 1974) The bone growth was computed from the increase in the distance between the intraosseous bone markers at repeated recordings The methodologic error in a growth rate determination based on two length measurements was $30.5\sqrt{2}\,\mu m = 43\,\mu m$ (ARONSON et coll 1977)

Table

Growth difference between the left and right rabbit tibia (L–R) after an unfractionated irradiation to the right leg at time 0 Difference in µm for the interval before (day −2–0) and for the nine intervals after irradiation and also total difference for the full test period after irradiation (0 75 5 days) Individual values for all rabbits and mean values for the group of rabbits receiving 0 1 Gy (10 rad) (2–7)

Absorbed dose Gy	Rabbit No	L–R in µm for the time intervals day −2 to 75 5									
		−2–0	0–7	7–9	9–14	14–17	17–42 4	42 5–45	45–72 5	72 5–75 5	0–75 5
24	1	− 6	2 583	1 029	2 681	1 320	9 201	766	5 940	324	23 845
0 1	2	− 8	78	56	3	1	1	45	18	5	203
	3	12	−255	12	−108	4	28	39	377	126	215
	4	38	28	164	247	−40	193	65	165	83	389
	5	73	− 64	15	56	− 23	118	29	31	− 13	198
	6	66	156	43	34	21	349	50	85	15	653
	7	27	− 49	84	160	− 20	329	29	− 93	43	581
	2–7										
	M	− 3	− 18	62*	7	− 11	44	5	97	29	114
	+ SEM	20	58	23	58	9	95	20	66	26	179
0	8	3	40	31	136	109	149	16	− 226	7	262

* almost significant, Student's t test

Irradiation The right calf was irradiated with a ^{137}Cs therapy unit The irradiation was given with a 100 mm long field through a standard applicator in close contact with the leg The whole tibial bone was covered in all instances The left leg was bent away from the radiation field and adequately shielded by lead The absorbed dose in the growth zones of the right leg was 24 Gy for rabbit 1, 0 1 Gy for rabbits 2 to 7 and 0 Gy for rabbit 8 Both legs received an additional 0 002 Gy to the epiphyseal cartilage for each stereophotogrammetric exposure

The rabbits were exposed to radiation at the age of 57 days This is denoted as time 0 Tantalum markers were inserted on day 30, and stereophotogrammetric recordings were made immediately after radiation and at days 2, 7, 9, 14, 17, 42 5, 45, 72 5 and 75 5

The radiation effects on growth were expressed as differences in growth between the left and the right leg (L–R) in µm The differences both for the whole test period of 75 5 days and for the eight intervals were computed

In the statistical analyses, the difference L–R was determined for each individual rabbit and for the group of rabbits 2 to 7 For the individual measurements, the L–R growth rate difference was considered significant if it was more than 129 µm (three times methodologic error of 30 5 $\sqrt{2}$ µm/interval) For the group of rabbits 2 to 7, a significant deviation of the mean value for the L–R difference was computed by t-test

Results

The daily growth rates of the right (irradiated) and left (non-irradiated) legs from day −2 of the investigation to day 75 (rabbit age 55 and 132 days, respectively) appear in the Figure There was a dramatic fall in growth rate of the irradiated right leg of rabbit 1 after 24 Gy In 7 to 9 days, the rate had fallen linearily to about 15 per cent of the original, within 42 days, the growth had completely ceased A very slight rise was noted on day 72 5 to 75 5

On the other hand, 0 1 Gy given to the right tibia of rabbits 2 to 7 had no effect on growth when the left and right legs were compared for the whole 75 5 day test period (Table) The mean L–R difference was only 114 μm and the SEM 179 μm. When the test period was subdivided, the difference in one of the eight periods was almost significant In day 7 to 9, the L–R difference was 62±23 μm For the non-irradiated rabbit 8, the growth difference between the two legs was 265 μm for the whole test period and between 3 and 226 μm during the eight intervals of the whole test period

The individual differences L–R were statistically significant (> 129 μm) for individual rabbits 2 to 7 in 10 of 54 intervals and for rabbit 8 in 3 of 9 intervals

Discussion

Roentgen stereophotogrammetry has been introduced for bone growth measurements in diagnostic radiology (ARONSON et coll 1975, ARONSON & SELVIK 1977) An objection to this method could be that the irradiation of the examined growth zone might disturb the growth process Therefore, it seemed necessary to determine whether a low radiation dose could interfere with growth

A linear dose response relation for the increase of the minimum stunting dose with age was demonstrated by HINKEL (1942) The lowest stunting dose for newborn rats was about 400 R This exposure corresponds to approximately 3 8 Gy in the epiphyseal cartilage (calculated according to ICRU No 17, 1970) in the growth zone, except for a 20 to 30 μm zone of increased absorption next to the calcified bone (SPIERS 1969)

Reports on the effect of doses below 4 Gy on the growth process are few and the results are not uniform HINKEL found no growth retardation below 5 Gy, BAUNACH (1935) could register a slight growth stimulation at about 1 5 Gy and [illegible]

[illegible] & [illegible]ERBURN 1960) BLACKBURN & WELLS (1963) found no change of ^{45}Ca uptake after 0 95 and 2 4 Gy The mitotic activity of the growth cartilage cells [illegible] known to be temporarily stopped by about 4 75 Gy but the effect of low doses is not known (BLACKBURN & WELLS)

[illegible] the [illegible] of [illegible] [illegible]entative maximum dose to be used in diagnostic

stereophotogrammetry. No difference was found after this dose, except for the period of day 7 to 9, when an almost significant difference in growth between irradiated and non-irradiated legs was observed In view of the remaining eight periods, when the differences were not significant, this single almost significant difference is compatible with chance It should also be noted that there was no radiation effect on the total growth during the 75 5 days after irradiation, as the difference in growth between the irradiated and the non-irradiated leg was not significant The absence of effect agrees with calculations of cell survival according to KEMBER (1967)

Thus no effect of 0 1 Gy was found but a dramatic fall in growth rate occurred after 24 Gy In eight days, it was only about 15 per cent of the original rate before irradiation After a period of complete arrest slight growth resumed, probably due to the appearance of recovery clones in the growth zone (KEMBER)

It was thought that the rabbit receiving no unilateral irradiation would serve as an ideal control animal and would show equal growth rates for the two legs But this was not so, which illustrates that, in the individual rabbit, growth rate normally may differ between the two legs with an alternate predominance for either leg In a group of rabbits, however, equal growth may be expected (HANSSON 1967)

As the results are based on differences between the left and right leg, an equal disturbance of the growth rate of both legs would not be detectable Therefore the results were not influenced by any effect of the additional 0 002 Gy given to both legs at each of the 10 measuring instances

Acknowledgement

The authors are greatly indebted to Docent Tord Olin for his generous support, including all facilities of the Laboratory of Experimental Radiology Funds from the University of Lund, from Landstinget M-l in, and from Stiftelsen Svensk Naringsforskning provided economic support

SUMMARY

The effect on bone growth of two locally given different, unfractionated radiation doses (0 1 and 24 Gy) was tested in a rabbit litter aged 57 days The effects on growth were registered with roentgen stereophotogrammetric length measurements for 75 days after irradiation Growth of the right irradiated tibia was compared with the growth of the left non irradiated tibia After 7 to 9 days, 24 Gy had caused a linear fall in growth to about 15 per cent After a period of complete cessation, a slight growth was registered 0 1 Gy had no significant growth retarding effect

ZUSAMMENFASSUNG

Die Wirkung von zwei lokal gegebenen, unterschiedlichen nichtfraktionierten Strahlendosen (0,1 und 24 Gy) auf das Knochenwachstum wurde an 57 Tage alten Kaninchen untersucht Die Wirkung auf das Wachstum wurde mittels rontgenstereophotogrammetrischen

Längemessungen 75 Tage lang nach der Bestrahlung registriert Das Wachstum der rechten bestrahlten Tibia wurde mit dem Wachstum der linken nichtbestrahlten Tibia verglichen 24 Gy hatten nach 7 bis 9 Tagen einen linearen Abfall im Wachstum von etwa 15 Prozent hervorgerufen Nach einer Periode vollständiger Hemmung wurde ein leichter Zuwachs registriert 0,1 Gy hatte keinen signifikanten Zuwachsherabsetzenden Effekt

RÉSUMÉ

Les auteurs ont expérimente sur une portee de lapins âges de 57 jours l'effet sur la croissance osseuse de 2 doses de radiations differentes, non fractionnees, administrees localement (0,1 et 24 Gy) Les effets sur la croissance ont été enregistres par des mesures de longueur stéréophotogrammetrique pendant 75 jours après l irradiation La croissance du tibia droit irradié a ete comparee avec celle du tibia gauche non irradié Au bout de 7 à 9 jours, la dose de 24 Gy avait causee un ralentissement lineaire de la croissance d environ 15 pour-cent Apres une période d'arret complet de la croissance on a observe une legere croissance La dose de 0,1 Gy n'avait pas d effet retardateur significatif sur la croissance

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RADIOLOGIC ASPECTS OF BCG-OSTEOMYELITIS IN INFANTS AND CHILDREN

W MORTENSSON, O EKLÖF and H JORULF

Based on a world wide experience, vaccination against tuberculosis by means of intracutaneous inoculation of living Bacilli Calmette-Guerin (BCG) is associated with a low rate of complications Nevertheless, approximately 20 cases of generalized BCG tuberculosis are on record in the literature representing all ages (DESPIERRES et coll 1951, HOLLSTRÖM & HÅRD 1953, MEYER 1954 THRAP-MEYER 1954, FALKMER et coll 1955, JAMES 1955, DZIENISZEWSKA-KLEPACKA & LEWICKI 1958 RAMON CLERRA [illegible] [illegible] et coll 1969, ŠICEVIĆ 1972, GERBEAUX et coll 1974) The course of the disease was almost invariably fatal This complication has been ascribed to immunologic deficiency (MATSANIOTIS 1967)

Haematogenous spread of the BCG infection to the skeleton, with osteomyelitis as the single clinical manifestation, has been described in some 60 cases (DICASA GRACIA 1936, MIMOUNI 1951, FALKENFLETH 1954, IMERSLUND & JONSEN 1954, MÖRKBAK 1954 HARALDSSON 1959, BANG et coll 1960, VIRTANEN & LINDGREN 1962, FELLANDER 1963, ENG & AANELAND 1966, WALLERSTRÖM & ENELL 1966, DAHL & HALVORSEN 1967, SINIOS 1968, ERIKSON & HJELMSTEDT 1971, WASZ HÖCKERT 1972,

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Table

Location of 32 lesions of BCG-osteomyelitis in 29 infants Number of cases with epiphyseal involvement given in parenthesis

Location	No of cases
Humerus, proximal metaphysis	2 (1)
Radius, distal metaphysis	2
Femur, proximal metaphysis	2
distal metaphysis	7 (5)
distal epiphysis	1
Tibia, proximal metaphysis	7 (4)
proximal epiphysis	1
distal metaphysis	3
Fibula, distal metaphysis	1 (1)
Sternum	3
Ribs	1
Tarsal bones	2

cases initially treated with penicillin As soon as the correct diagnosis was established, penicillin was substituted by anti-tuberculous drugs This treatment was in 28 patients supplemented by surgical evacuation of bone abscesses

Radiologic considerations

The time interval between the appearance of symptoms and signs and the first radiography was in 25 cases 1 to 10 days, in the remaining 4 patients between 11 days and 2 months

In searching for non-symptomatic bone lesions, radiography of the whole skeleton was carried out in 9 patients Only one, minimal, silent focus was detected

Three patients presented two separate lesions Thus, in all 32 lesions existed and their appearances were analysed, the locations are presented in the Table

The most common radiologic feature, present in 18 lesions, was a well demarcated, excentrically located destruction in the metaphysis of one of the long bones and break-through of the cortex with the inflammatory process extending into the surrounding soft tissues (Figs 2–5) Periosteal reaction, if present, was slight The periosteum was frequently elevated near the destruction (a 'beak') indicating a rapid progress of the lesion (Fig 2b, c) In most cases no dissemination of the infection occurred into the diaphysis or beneath the periosteum Sclerosis in the vicinity of the destruction was either absent or very scant The dead bone within the lesion was completely resorbed and thus sequestration never occurred In addition to the metaphyseal lesions, involvement of the adjacent epiphysis occurred in 11 cases (Fig 4), at operation a narrow fistula was found connecting the metaphyseal and

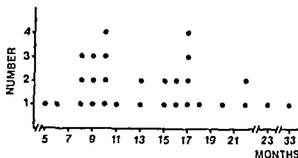


Fig 1 Age at appearance of symptoms and signs

HENRIKSON et coll 1974, KÜHNER & GEKLE 1975) Neither defects in the immunologic defence, nor changes in the virulence of the BCG-strains used, seem to be responsible for the evolution of the condition (IRVINE 1949, MANDE 1968, ENG & AANTLAND 1966) However, gradual changes in the strength of the reference strain may have occurred (FOUCARD 1975)

The radiologic appearance of BCG-osteomyelitis is only briefly discussed in the literature The purpose of this report is to present an analysis of the observations made in a comparatively large series

Material and Methods

The material consisted of 17 boys and 12 girls, born in the period 1958–1974 2 cases in the period 1958–1959, 6 in 1965–1969, 6 in 1970–1971, 13 in 1972–1973 and 2 cases in 1974 All patients were inoculated intradermally during the first week of life by means of a vaccine containing a Swedish BCG-substrain

As a rule the symptoms and signs were vague In some cases osteomyelitis was suggested incidentally Symptoms and signs became evident between 5 and 33 months of age (Fig 1) They consisted of a tender swelling, usually located near a joint, restriction of movements, slight to moderate elevation of the erythrocyte sedimentation rate, and in some cases of slight fever The general condition was not affected

In 28 patients biopsy specimen obtained from the bone lesions revealed epithelioid cell granulomas with caseous necrosis and Langhans' giant cells In one patient no microscopy was performed, however, a BCG-strain was cultured from pus from the skeletal lesion

Acid-fast rods were demonstrated on direct microscopy of the pus in 4 out of 18 cases Culture on Lowenstein's medium was performed in 26 cases, in 13 of them growth of acid-fast rods occurred In 12 cases typing of the outgrown rods was performed and the bacilli were indistinguishable from the BCG-strain used at vaccination Guinea-pig tests were carried out in 23 cases and they were invariably negative Cultures for pyogenic microbes were negative in the whole series

No abnormality was found on radiography of the chest in 27 patients, the remaining two infants had no such examination performed

On the assumption of a simple pyogenic infection, the osteomyelitis was in several

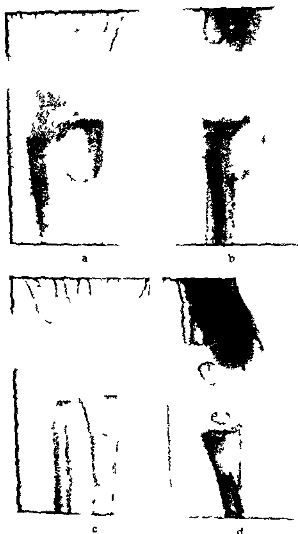


Fig 3 a, b) Boy aged 9 months After 4 weeks of penicillin treatment of a tender swelling in the wrist A large well delineated destruction in the distal radius The periosteum is elevated on the volar side c, d) Five months after surgical evacuation the bone structure is almost normal

sided temporarily reappearing one year later At this occasion a slight fever and an increased ESR were also present In another 5 patients submitted to radiography between 2 and 10 days after osteomyelitis became clinically evident, the lesions consisted of small areas of decalcification At the subsequent examination carried out after 7 10 14 20 and 30 days respectively large destruction of the bone had developed (Fig 2)

Following treatment healing of the lesions gradually occurred in all cases persisting radiologic sequelae were exceptional (Figs 3–5) Slight functionally insignificant bone deformation occurred in 2 cases About 2 years after the beginning of treatment increased growth in length of the affected extremity became evident in 2 of the cases However no systematic investigation on this feature was performed

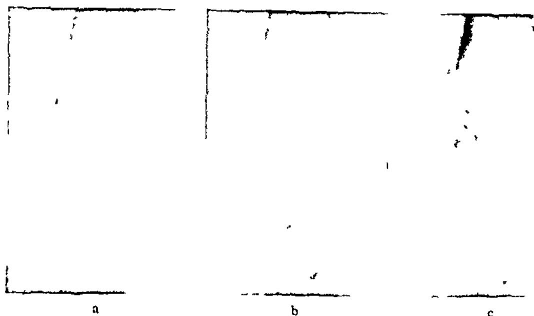


Fig 2 Boy aged 7 months a) Restriction of movement and a tender swelling of the right knee A small area of decalcification in the lateral part of the distal metaphysis of the femur b) Ten days later a well delineated destructive lesion has developed c) Another six days later Progression of the lesion Periosteal 'beak'

epiphyseal foci, which therefore were appreciated as single lesions In another 3 cases the same radiologic features could be noticed, but without cortical breakthrough However, in one of the latter cases, perforation of the cortex was disclosed at surgery

When the lesion was located in the sternum, the ribs or the tarsal bones, marked destruction of spongeous and cortical bone and no or only slight sclerosis were almost as common as with long bone involvement However, the radiologic appearance was less characteristic (Fig 6)

In 3 patients, only the epiphysis of a long bone was affected

In 2 cases the appearance was different, the lesions were extensive and involved a rather large part of the diaphysis The affected bone became slightly deformed Formation of new bone became extensive, resulting in a multicystic appearance which was especially marked in one of the patients (Fig 7)

Degenerative arthritis with destruction of the joint cartilage or deformity of the bone did not occur in this series, not even in a patient with microscopically confirmed tuberculous arthritis (Fig 5)

No correlation was found between the extension of the lesion at the first radiologic examination, and the age of the patient at which symptoms and signs of osteomyelitis became apparent With few exceptions bone destruction was well established already ... nce of symptoms

unambiguous tenderness of the knee and restricted movements The complaints sub



Fig 6 Boy aged 8 months with a tender tumour of the thorax. Well delineated destruction in the subjacent rib Break through of the process found at surgery

Discussion

Haematogenous spread of BCG and formation of epithelioid cell granulomas of different localizations is an ordinary consequence of the BCG vaccination (GORMSEN 1955 SÉNÉCAL et coll 1956 STOJANOV & ZAGUROV 1963 animal experiments STRÖM & WIDSTRÖM 1951 VOGELSANG et coll 1960) The granulomas resolve spontaneously within 40 months of the vaccination without causing clinically obvious signs (GORMSEN 1955)

In the present series the diagnosis was mainly based upon the microscopy of biopsy specimen Epithelioid cell granulomas with caseous necrosis and Langhans giant cells are regarded as highly characteristic albeit not pathognomonic of tuberculosis Diagnostic alternatives as sarcoidosis fungus infection and syphilis may be excluded on the basis of the clinical and radiologic findings However BCG tuberculosis cannot be distinguished from tuberculosis caused by bacilli of the human type or from tuberculosis produced by bacilli of other bovine types on the microscopic appearance alone Therefore the diagnosis of BCG osteomyelitis was proved beyond doubt only in cases in which acid fast rods were successfully cultured which behaved like the BCG strain used at vaccination It is less likely that the bone lesions in the remaining cases would be caused by tuberculosis of the human type The age of the patients absence of other foci of tuberculosis of human type the mitigative course of the disease and the apathogenicity of the bacilli to guinea pigs all speak against this possibility The negative results of culture on Lowenstein s medium in half the cases do not exclude BCG as the causative agent Penicillin therapy given to



a b c

Fig 4 a) Boy aged 17 months limping and joint effusion observed one day before radiography
Large well delineated area of destruction in the metaphys
surroundings Small destruction in the adjacent epiphysis
later Progression of the lesions and moderate periosteal
surgery Minor persisting abnormality of the bone structure

a b

Fig 5 a) Large destruction in the femur neck in a 15 month old girl limping since 12 days The process perforated to the joint and tuberculous synovitis was microscopically confirmed b) Two years later complete healing

involvement remains obscure It may partly depend upon simple diagnostic mistakes partly on the difficulties in securing satisfactory biopsy specimen from the vertebrae

Conclusions

BCG-osteomyelitis in infants and young children is characterized by the rapid development of a well demarcated destruction, usually located excentrically in the metaphysis of a long bone It may occasionally involve also the epiphysis A strong tendency to a break through of the cortex exists but no or only slight spread of the infection along the shaft The periosteal reaction is scarce Exceptions from these rules may occur In most cases included in the present series the radiologic features still appeared characteristic enough to suggest the diagnosis of BCG-osteomyelitis

SUMMARY

An account is given of results of the radiologic examination of 29 infants and children with bone tuberculosis caused by the Bacilli Calmette–Guérin (BCG) as a complication to intradermal vaccination The diagnosis is based on radiologic appearances microscopy and bacteriologic examination of specimens obtained from the bone lesions The radiologic appearance of the bone lesions is in most cases characteristic and differs decisively from that of pyogenic osteomyelitis and malignant disease

ZUSAMMENFASSUNG

Die Ergebnisse der rontgenologischen Untersuchungen von 29 Kindern und Jugendlichen mit Knochentuberkulose, die durch Bacilli Calmette Guerin (BCG) als Komplikation der intradermalen Vakzination hervorgerufen worden war, werden berichtet Die Diagnose stutzt sich auf das rontgenologische Bild, die mikroskopische und bakteriologische Untersuchung der Proben der Knochenveranderungen Das rontgenlogische Bild ist in den meisten Fällen charakteristisch und unterscheidet sich klar von einer pyogenen Osteomyelitis und einer malignen Erkrankung

RÉSUMÉ

Les auteurs présentent les résultats de l examen radiologique de 29 nourrissons et enfants atteints *de tuberculose osseuse causée par le bacille de Calmette* et Guerin (BCG) comme complication de la vaccination intra-dermique Le diagnostic est basé sur les aspects radiologiques sur les examens microscopiques et bactériologiques de prélèvements des lésions osseuses L aspect radiologique des lésions osseuses est dans la plupart des cas caractéristique et diffère nettement de celui de l ostéomyélite a pyogène et de celui des affections malignes

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Fig. 7. a) Tender swelling in the fore arm and restriction to movements appeared at the age of 22 months. Extensive destruction of the distal radius, deformation and moderate periosteal reaction. Cortex destroyed at several sites but no break through. No treatment given at this stage. b) 13 months later. Progression of the lesion and endosteal new bone formation resulting in a multicystic appearance of the bone.

several of the patients for a varying periods before the culture, may contribute to this failure as BCG-strains are known to be susceptible to some kinds of penicillin.

The appearance of the BCG-osteomyelitis agreed with previously published descriptions. Pyogenic osteomyelitis, Ewing's sarcoma or metastases of malignant tumours occasionally have to be considered as diagnostic alternatives at radiography, the absence of sequestrum formation, absence of spread along the shaft of long bones, distinct demarcation of the destruction, scant sclerosis and periosteal reaction are all features speaking against these diagnostic alternatives. Only in cases of isolated involvement of an epiphysis or a small bone nucleus, does the radiologic differentiation between a BCG-infection and a low-virulent pyogenic infection appear impossible.

It should be pointed out that also in bone tuberculosis of the human type, the lesions are essentially destructive in nature. A limited degree of osteosclerosis and scarce formation of new bone in combination with a minor periosteal osteogenic activity are other features recorded (Edeiken et coll. 1963).

Regarding the fact that bone tuberculosis of the human type most frequently ... case of BCG spondylitis ... in the present ... rience. There seems to be only one case of BCG-spondylitis on record, found at autopsy of a patient who died in a general BCG-tuberculosis (Thrap-Meyer 1954). The reason for this difference

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vaginally, proving the capacity of their birth canal, are not routinely examined with roentgen pelvimetry

The sagittal measurements were performed by the method of BORELL & FERNSTRÖM (1960) (patient lying on the side) and the transverse measurements by the method of BORELL & RÅDBERG (1964) This gives the lengths of the sagittal inlet and outlet, as well as those of the transverse outlet (interspinous and intertuberous diameters) The transverse inlet diameter was measurable only in 20 per cent of the cases because the field of exposure was purposely kept small to give the least possible radiation to the mother and fetus

The method was tested in a small number of women above child-bearing age and it was found that its reproducibility lay within ± 1 mm

As a reference group was used a material of pelvimetry of 100 patients without pelvic disproportion clinically but where induced labor was contemplated

The indications for pelvimetry were toxemia of pregnancy, duration of pregnancy unknown or in doubt, diabetic mother, possible multiple pregnancy or possible fetal death

Results

Average measurements obtained in the breech group as compared with those in the normal group are presented in the Table

Statistical analysis (one sided t-test) shows the differences of interspinous diameter, intertuberous diameter and the sum of outlet diameters to be significant ($p < 0.01$) with the differences in intertuberous diameter and in the sums of the outlet diameters highly significant ($p < 0.001$) The number of observations on transverse inlet diameter was only 44

Discussion

Different human populations have different pelvic measurements and the average pelvic size is probably larger now than 30 years ago It is therefore necessary to establish values from a group of normal cases within the population to which the breech cases belong (Southern Sweden) The radiation hazard precludes the use of roentgen pelvimetry to obtain measurements in a strictly normal random population Thus, the normal cases had to be selected from a material of women in which pelvimetry had been performed By excluding cases with a small pelvis clinically, the selection of the normal group may be biased, tending to give larger values than the true mean However, the difference is probably small, and the results are well within the range given in other reports (BORELL & FERNSTRÖM 1960, BORELL & RÅDBERG 1964, DIEHL & FERNSTRÖM 1966) It is quite evident that no great difference exists between the measurements of the present two groups

It is well known that one causative factor in breech presentation (and probably the most important one) is the accommodation of the fetus to the shape and size of the uterine cavity This could explain why breech presentation is progressively more common with decreasing birth weight until, at a fetal weight of 500 to 1 000

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PELVIMETRY IN BREECH AND CEPHALIC PRESENTATION

S LAURIN, V HEGEDÜS and S ZURBRIGGEN

Breech presentation occurs in about 3 per cent of human births (TOMPKINS 1946, HECKLINGER 1960) It still carries a higher perinatal morbidity and mortality than cephalic presentation, although part of the difference is explained by the greater *number of premature births in breech presentation* Earlier *textbooks have considered* pelvic disproportion one of the causes of breech presentation but VARTAN disproved this as early as 1940 However, a few recent reports still describe pelvic disproportion as a common phenomenon in breech presentation (ANDAYA & FIESTA 1966, MUXI et coll 1969, PERLMANN 1973) If a small or deformed maternal pelvis were a causative factor, it would be reasonable to expect a smaller then average pelvic size in women delivering in this manner However, instead of small pelvic measurements, the occurrence of some breech cases with unusually large pelves was observed in this hospital This fact and the fact that no large series has previously been published on radiologic pelvimetry in breech versus vertex presentation initiated the present report

Material and Method The pelvimetries on patients admitted from the obstetric clinic during the period 1968 through 1970 and with breech deliveries were reviewed, excluding cases of prematurity (fetal weight below 2 500 g) A total of 115 cases were found

The patients were mostly primiparae, since women who have previously delivered

Submitted for publication 5 December 1975

Table (*cont*)

Intertuberous diameter		Sagittal outlet diameter		Sum outlet diameters	
Breech	Normal	Breech	Normal	Breech	Normal
115	100	115	100	115	100
11 9	11 4	12 0	11 8	34 5	33 4
9 4–15 3	8 8 15 4	9 7–14 8	8 8–14 5	29 1–40 7	29 0–42 8
1 260	1 131	0 990	1 014	2 360	2 180
0 5		0 2		1 1	

pelvic measurements were all a few mm larger in the breech cases and the average sum of the outlet diameters was significantly larger Pelvic disproportion was not more common in breech presentation and no support was found for the theory that large pelvic measurements predispose to breech presentation The small differences found are attributed to the moulding of the pelvis occurring during parturition

ZUSAMMENFASSUNG

Die Beckenmasse bei einer Gruppe von 115 Frauen, die in Steisslage niedergekommen waren wurden mit denen einer Gruppe von 100 Frauen, die in Schädellage niedergekommen waren verglichen Die durchschnittlichen Beckenmasse waren alle bei den Fällen mit Steisslage einige mm grosser und die durchschnittliche Summe des ausseren Diameters signifikant grosser Ein Missverhaltnis des Beckens war bei der Steisslage nicht gewohnlicher und es wurde keine Stutze fur die Theorie gefunden, dass grosse Beckenmasse fur eine Steisslage pradisponieren Die geringen beobachteten Unterschiede konnen auf die Formung des Beckens die wahrend der Geburt geschieht, zuruckgefuhrt werden

RÉSUME

La mesure des diamètres pelviens chez un groupe de 115 femmes accouchant en présentation par le siège a été comparée à celle d un groupe de 100 femmes [illegible]

[illegible] plus grande La disproportion pelvienne n est pas plus fréquente dans la présentation du siège et les auteurs n ont pas trouvé de confirmation à la théorie que les grands diamètres pelviens prédisposent à la presentation su siège Les petites différences constatées sont attribuées au modelage du bassin qui se produit au cours de l accouchement

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Table

Comparison of pelvic measurements in 115 breech cases and 100 normal cases

	Sagittal inlet diameter		Transverse inlet diameter		Interspinous diameter	
	Breech	Normal	Breech	Normal	Breech	Normal
No of cases	115	100	25	19	115	100
Mean (cm)	12 5	12 3	13 8	13 4	10 5	10 3
Range (cm)	10 2–15 1	9 1–14 1	12 2–15 7	12 2–15 0	8 8–12 9	8 7 13 5
SD (cm)	0 970	0 986	0 724	0 923	0 870	0 794
Difference (cm)	0 2		0 4		0 2	

g, 40 per cent of deliveries occur in the breech position (SCHRAGE 1973, TOMPKINS 1946) Then, an unusually large pelvis in relation to a normal-sized infant could perhaps give rise to such a change in uterine shape that breech presentation would be more common The small differences presented here, albeit statistically significant, do not warrant a conclusion in that direction, particularly since the significant differences were found in the outlet diameters, which should not influence the size or shape of the uterine cavity Hence, there is no support for the theory that a large pelvis influences the position of the mature infant

If pelvic size had any marked influence on the position of the fetus, repeat breech presentation would be common This presentation is also more common than suggested statistically However, this fact is generally considered as caused by a congenital anomaly, a more or less septate uterus, which changes the accommodation possibilities of the fetus (SMITH 1933, TOMPKINS 1946, HECKLINGER 1960) In the present group of breech presentation there were 4 repeat breech births above 2 500 g, and one below 2 500 g One patient delivered 3 times in breech presentation (birth weights 2 720, 2 650 and 2 250 g, respectively) The pelvic measurements in these cases were not abnormal

It is known that moulding of the pelvis occurs during parturition (BORELL & FERNSTRÖM 1957), so that both the sagittal inlet and the outlet diameters increase by up to 10 mm when the head passes Much smaller changes of the transverse diameters have been reported The present normal cases were all examined before passage of the head into the birth canal, i e before moulding had occurred, whereas many of the breech cases were examined during parturition when there was time for moulding to occur This could be the explanation for the increase by some mm in all diameters

SUMMARY

Pelvic measurements in a group of 115 women delivering in breech presentation were compared with those in a group of 100 delivering in cephalic presentation The average

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VERTEBRAL MOTION IN SPONDYLOLISTHESIS

T H OLSSON, G SELVIK and S WILLNER

In order to measure the forward displacement of one vertebra in spondylolisthesis, a grading system was suggested by MEYERDING (1932) He divided the upper surface of the body of the first sacral vertebra into four equal parts The degree of spondylolisthesis was then graded according to this scale This system was further developed by NEWMAN (1965) who drew one line along the superior and one along the anterior surface of the first sacral body and divided each line into ten equal parts The degree of displacement was then measured according to the position of the postero-inferior corner of the body of the fifth lumbar vertebra in relation to these two lines This method was also used by DANDY & SHANNON (1971) who complemented it with 'a method of measurement of roll' They measured the angle between the lower surface of the first sacral body and a diagonal line drawn between the antero-superior and postero-inferior corners of the body of the fifth lumbar vertebra as seen in a lateral view By this method it was possible to follow the successively developing rotation of the vertebra in question Although the general displacement in spondylolisthesis could thus be evaluated a true three-dimensional analysis was not rendered possible until the roentgen stereophotogrammetric method was developed (SELVIK 1974) This method was therefore used to elucidate the motions in the lower lumbar region in spondylolisthesis in four patients

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Case reports

Case 1 Woman, 46 years old, with spondylolysis of L5 and spondylolisthesis between L5 and S1 (grade 1 according to MEYERDING) Conservative treatment being without effect, a posterolateral fusion was performed from L4 to S1 (previously described by OLSSON et coll 1976 a) Tantalum indicators necessitated by the roentgen stereophotogrammetric method were inserted into the posterior elements of L3, L4 and S1 during the operation by the method of ARONSON et coll (1974) In addition the segments anterior and posterior to the lysis in the arches of L5 were indicated separately The patient was examined supine 57 days postoperatively during recumbency in a plaster bed She was then mobilized and was examined in standing positions 111 days postoperatively

Case 2 Woman, 22 years old, with spondylolysis of L5 and spondylolisthesis between L5 and S1 (grade 1) A posterolateral fusion from L4 to S1 was performed (also described by OLSSON et coll 1976 a) Indicators were inserted during the operation into L4, L5, and S1, and again the two parts of L5 were indicated as two separate segments Examinations as in Case 1 were performed 62 and 109 days postoperatively

Case 3 Man, 37 years old, with spondylolysis of L5 and spondylolisthesis between L5 and S1 (grade 1) The patient had 2 years previously been operated upon by the method of BUCK (1970), with an attempt to fuse the lysis using screws through the interarticular parts of the arches This attempt was a failure and the screws were removed During the latter operation the posterior elements of L4, L5, and S1 were provided with indicators The segment anterior to the lysis of L5 was not indicated Examinations in the supine and in standing positions were performed 290 days after the second operation

Case 4 Woman, 52 years old, with spondolysis of L4 and spondylolisthesis between L4 and L5 (grade 1) as well as slight degeneration of the disks L2 L3 and L3–L4 Because of sciatic pain with neurologic deficits, a decompression with removal of the posterior element of L4 (GILL procedure) was performed During the operation tantalum indicators were inserted in the posterior elements of L2, L3, and L5 Examinations were performed in the supine and in standing positions 150 days postoperatively In all patients the standing positions included erect standing, flexion and extension

Methods

The Eulerian rotations and the translations for each indicated segment in relation to a subjacent segment about and along the axes of a Cartesian coordinate system from one position to another were determined by computer assisted technique (OLSSON et coll 1976 b) The axes of the coordinate system were determined by the axes of a calibration cage that was exposed before the exposure of the patient on each film The x-axis approximated a transversal, the y-axis a longitudinal, and the z-axis a sagittal axis (see Fig 1 in OLSSON et coll 1976 a), as the patient was placed as straight as possible in relation to the cage at the reference examination

The precision of the method was estimated by re-evaluation of seven films each from cases 1 and 2, as well as seven films from case 3 in OLSSON et coll (1976 a), the indicators in the latter being placed in similar positions to those in the present cases 3 and 4 Cases 1 and 2 were evaluated according to their own precision tests, while

Table 1

The mean errors of rigid-body fitting for each segment of the four cases in the given movements (unit μm)

		S1	L5 (post segm)	L5	L5 (ant segm)	L4	L3	L2
Case 1	Supine–erect standing	51	64		73	59	58	
Case 2	Supine–erect standing	22	45		111	107		
	Flexion	27	31		102	56		
	Extension	28	38		90	52		
Case 3	Supine–erect standing	50	18			67		
	Flexion	32	15			49		
	Extension	65	30			44		
Case 4	Supine–erect standing			37			50	97
	Flexion			57			35	62
	Extension			14			108	107

cases 3 and 4 of the present material were evaluated by means of the third precision test, the reason being that different positions of the indicators cause different precision values, (OLSSON et coll 1976 a)

Results

The mean errors of rigid body fitting (e_{rb}) for each segment are given in Table 1 They ranged between 14 and 111 μm

The standard errors s_ϕ, s_ψ, and s_θ for the rotations obtained from the precision tests are accounted for in Table 2 (7 d f for Tests 1 and 2, 14 d f for Test 3) The values in conjunction with Student's t test were utilized for computing significant motions and differences between motions

The rotations about the three coordinate axes for each indicated segment in relation to a subjacent one, appear in Figs 1 and 2, where each staple group represents the rotation of one segment in relation to another indicated segment In the diagrams, stippled staples stand for the rotations relative to the x-axis, filled staples refer to the y axis, and striped staples represent the rotations about the z axis The diagrams render a complete description of the rotations, whereas the text accounts for only those rotations of particular interest When describing these motions, the symbols α_x, α_y, α_z are used for the rotations about the x-, y-, and z-axes, respectively

Positive rotation about the x axis is defined as a forward rotation of the cranial part of the segment in question Positive rotation about the y axis is defined as a rotation moving the ventral part of the segment towards the left side and this rotation is described as counter-clockwise Positive rotation about the z-axis is a rotation of the cranial part of the segment in question towards the right side of the patient

Table 2

The standard errors s_ϕ, s_ψ and s_θ for the rotations for the segment pairs given in the three precision tests (unit degree) (7 d f for Tests 1 and 2, 14 d f for Test 3)

		S_ϕ	S_ψ	S_θ
Test 1, case 1	L3–L4	0 09	0 12	0 07
	L4–L5(ant segm)	0 23	0 18	0 06
	L4–L5(post segm)	0 10	0 12	0 06
	L5(ant segm)–S1	0 30	0 25	0 07
	L5(post segm)–S1	0 25	0 25	0 10
Test 2, case 2	L4–L5(ant segm)	0 21	0 05	0 05
	L4–L5(post segm)	0 22	0 08	0 06
	L5(ant segm)–S1	0 37	0 17	0 05
	L5(post segm)–S1	0 21	0 19	0 07
Test 3	L3–L4 + L5–S1	0 12	0 13	0 07

The anterior and posterior segments of L5 will be referred to as L5(ant segm) and L5(post segm), respectively

The translations showed slight forward displacements of the vertebrae with lysis relative to their subjacent vertebrae between the supine and the erect standing positions but are not further described in this connection

The movements demonstrated for the four cases between the supine and erect standing positions appear in Fig 1 The rotations about the x-axis for cases 1 to 3 were directed forwards between L5(ant segm)–S1 and between L5(post segm)–S1 ($\alpha_x \sim 3$ 0°, stippled staples) while the simultaneous rotations about the x-axis for these cases between L4–L5(post segm) were directed backwards ($\alpha_x \sim -2$ 0°) In addition, the same rotation for case 2 between L4–L5(ant segm) was also directed backwards ($\alpha_x = -1$ 0°) while it was not significantly different from zero for case 1 between these segments L5(ant segm) in case 3 was not supplied with indicators The rotations about the x-axis for case 4 were 1 1° between L3–L5 and –3 7° between L2–L3, the former directed forwards and the latter backwards

In case 1 significant rotations about the y-axis was not encountered The rotations were to the left about the z-axis, however, between L5(ant segm)–S1 ($\alpha_z = -1$ 0°) and between L5(post segm)–S1 ($\alpha_z = -0$ 7°), while the same rotation was to the right between L4–L5(ant segm) ($\alpha_z = 0$ 2°) and between L3–L4 ($\alpha_z = 0$ 6°) In case 2, a clockwise rotation about the y-axis ($\alpha_y = -1$ 4°) between L5(ant segm)–S1, and a counter-clockwise rotation about the same axis ($\alpha_y = 0$ 7°) between L4–L5(ant segm) were noted Simultaneously in case 2 a rotation occurred to the left about the z-axis between both L4–L5(ant segm) ($\alpha_z = -2$ 1°) and between L4–L5(post segm) ($\alpha_z = -2$ 3°), while the rotations between L5(ant segm)–S1 and between L5(post segm)–S1 were close to zero Almost no significant rotations between the two segments of L5 in case 1 and 2 were demonstrated The rotations about the y-axis

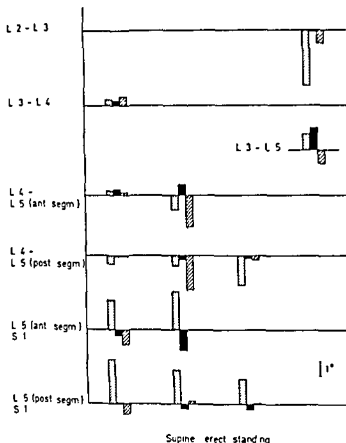


Fig 1 From left to right Cases 1, 2, 3, and 4 respectively The rotations for the segment pairs given during the movements from the supine to the erect standing positions Stippled staples stand for the rotations relative to the x axis filled staples for the y axis, and striped staples for the rotations about the z axis

in case 3 were not significantly different from each other The same was true for the rotations about the z axis In case 4 the rotation 1 5° counter-clockwise about the y axis between L3–L5 was found while the same rotation between L2–L3 was 0 0°

The movements between the erect standing position and both the flexed and extended standing positions appear in Fig 2 Case 1 is excluded from the description because the motions in question were not significantly different from zero, probably due to postoperative pain In case 2 there were forward rotations for L5(ant segm)–S1 and for L4–L5(ant segm) (α_x=1 3° and 4 5°) at flexion and backward rotations for these segment pairs at extension The rotations about the y-axis were in opposite direction to each other between L5(ant segm)–S1 and between L4–L5(ant segm) at both flexion and extension, and the rotations about the z-axis were in opposite direction between the same segment pairs at extension In case 3 the rotation about the x axis between L5(post segm)–S1 was 5 9° and the same rotation between L4–

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		S_ϕ	S_ψ	S_θ
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	L4–L5(ant segm)	0 23	0 18	0 06
	L4–L5(post segm)	0 10	0 12	0 06
	L5(ant segm)–S1	0 30	0 25	0 07
	L5(post segm)–S1	0 25	0 25	0 10
Test 2, case 2	L4–L5(ant segm)	0 21	0 05	0 05
	L4–L5(post segm)	0 22	0 08	0 06
	L5(ant segm)–S1	0 37	0 17	0 05
	L5(post segm)–S1	0 21	0 19	0 07
Test 3	L3–L4 + L5–S1	0 12	0 13	0 07

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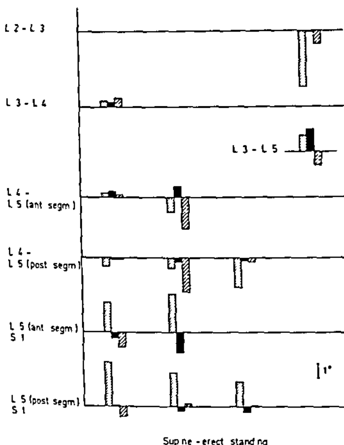
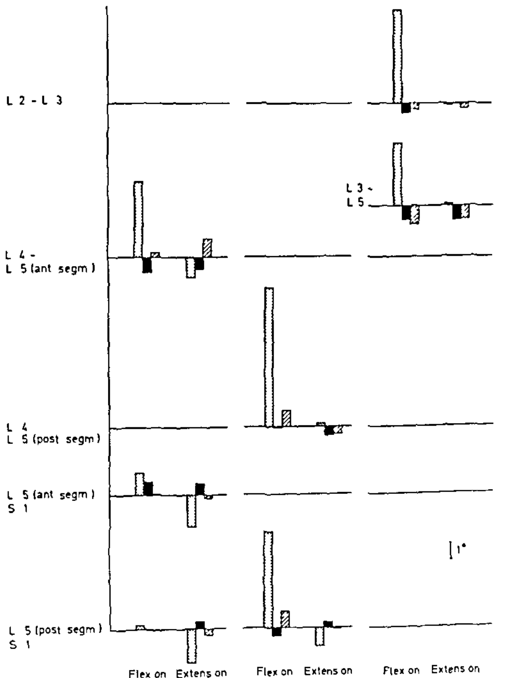


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The movements between the erect standing position and both the flexed and extended standing positions appear in Fig 2 Case 1 is excluded from the description because the motions in question were not significantly different from zero, probably due to postoperative pain In case 2 there were forward rotations for L5(ant segm)–S1 and for L4–L5(ant segm) (α_x = 1 3° and 4 5°) at flexion and backward rotations for these segment pairs at extension The rotations about the y-axis were in opposite direction to each other between L5(ant segm)–S1 and between L4–L5(ant segm) at both flexion and extension, and the rotations about the z-axis were in opposite direction between the same segment pairs at extension In case 3 the rotation about the x-axis between L5(post segm)–S1 was 5 9° and the same rotation between L4–



L5(post segm) was 8 3° at flexion At extension, the rotations for the two segment pairs were significantly different from each other In case 4, the motion about the x-axis was the same as in the two previous cases at flexion At extension there were significant differences in the rotations about the y- and z-axis for the two segment pairs

Discussion

The mean errors of rigid-body fitting did not notably exceed 100 μm (maximal value = 111 μm, which value corresponds to the limit for measurement errors (OLSSON et coll 1976 a) Thus there is no evidence that the indicators in each segment have not behaved according to the rigid-body model

The motion can be described as that of an unstable pile of blocks Thus the forward rotations about the x-axis between the two segments of L5 and S1 in case 1 in the comparison between the supine and the erect standing positions were significantly different from the rotations between L4 and the two segments of L5 In cases 2 and 3 the forward rotations for the segments of L5 were accompanied by backward rotations for L4 The pattern of motion was most obvious in case 4, which case, however, was different from the other cases as the vertebra with lysis was not supplied with indicators The directions of the rotations were opposite to each other about the y axis in case 2, both between the supine and the erect standing positions and between the standing positions Significant differences for the rotations about the y axis between the two segment pairs were also found in cases 3 and 4 Such a difference between the rotations about the z-axis was found in all four cases

Thus an instability of motion around all three coordinate axes was demonstrated The rotations about the x-axis were of the same type as those described by DANDY & SHANNON, even if they described only the forward rotation for the vertebra with lysis The instability was observed only with limited rotations An example is the rotation which occurs between the supine and erect standing positions The motion is therefore different from 'the paradoxical angulations' described by SCHALIMTZEK (1958) as they were observed during maximal rotations It is also different from the 'deviation from the normal pattern of motion' observed by GIANTURCO (1944) as this deviation refers to the axis of the rotation and not to the direction of the rotation The 'hidden effects' observed between 'mid positions' by HOAG et coll (1960) seems, however, to be of the same nature as those observed in the present material Thus they state 'for certain cases of spinal motion, the vertebrae do not move in a continuous clockwise sense, but 'wobble' back and forth' A similar mobility was also found by ROLANDER (1966) in a normal specimen from a five year-old child He found a forward rotation for L2 and backward rotations for L3 and L4 during longitudinal loading of the specimen Therefore, at the present stage of knowledge it is not possible to say if the disharmony of motion found in the present material is of etiological importance in the complaints associated with spondylolisthesis, although several authors claim that abnormal movements between vertebrae may be the cause of pain (KNUTSSON 1944, SCHALIMTZEK, CLOWARD 1963)

SUMMARY

Four cases with spondylolisthesis of grade 1 caused by spondylolysis were examined with a roentgen stereophotogrammetric method Disharmonic motion between the vertebrae was detected and quantified

ZUSAMMENFASSUNG

Vier Fälle mit Spondylolisthesis des Grades 1, hervorgerufen durch eine Spondylosis, wurden mit einer Rontgen Stereophotogrammetrischen Methode untersucht Es wurde disharmonische Bewegungen zwischen den Wirbeln gefunden und quantitativ erfasst

RÉSUMÉ

Quatre cas de spondylolisthesis de degré I causé par spondylolyse ont été examinés par une méthode radiologique stéréophotogrammétrique Cette méthode a mis en évidence une mobilité dysharmonieuse entre les vertèbres et a permis de la mesurer

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RADIOGRAPHIC MEASUREMENTS ON THE RADIO-CARPAL JOINT IN DISTAL RADIAL FRACTURES

S. FRIBERG and B. LUNDSTRÖM

The fracture of the distal part of the radius, fractura radii typica loco classica (Colles' fracture), is the *most common fracture* in man and amounts to 10 per cent of *all* fractures in the human skeleton.

In general, one third of *the treated cases* has been found to have residual symptoms from the wrist after healing of the fracture (GARTLAND & WERLEY 1951, BACORN & KURTZKE 1953, WIKLUND & MÜLLERN-ASPEGREN 1956). However, FRYKMAN (1967) *reported* a frequency of remaining *symptoms* as high as 77 per cent. Strong evidence exists that *permanent malposition of the fragments* in the form of radial compression or excessive dorsal angulation is one of the major causes of persistent weakness, pain and permanent loss *of normal function in the* wrist (NISSEN-LIE 1939, LIDSTRÖM 1959, FRYKMAN 1967). This *emphasises the* importance of achieving as correct an anatomic repositioning as possible and to maintain this position during healing of the fracture. Repeated radiography is *necessary and* each examination must allow a correct and reproducible evaluation of the *position* of the fragments. It is difficult to achieve corresponding projections in *routine* radiography of the wrist, particularly in the lateral view and when the wrist is covered [illegible]

projections for the evaluation of the normal radio-carpal joint in the lateral view (FRIBERG & LUNDSTRÖM 1976) This report deals with the influence of different projections and moderate degrees of pronation or supination of the wrist on the estimation of the inclination of the joint surface of the radius in the lateral view in cases with distal radial fractures

Material and Methods

Forty wrists with a fracture in the distal part of the radius were examined in 37 adults In the lateral view the distal radial joint surface had varying angular displacements in the dorsal direction The radial side was compressed in 11 of the fractures, i e the inclination of the joint surface in the ulnar direction was 15° or less

Radiographic technique A skull table (Elema-Schonander) with FFD 70 cm was used During the examination the arm was abducted 90° at the shoulder joint and flexed 90° at the elbow For the postero-anterior projection the palm of the hand was placed against the cassette and one view with the central ray at right angles to the film was exposed In the lateral projection the forearm was supinated and the hand was held in an exact position by a special immobilizing device In this position the wrist was examined with two series of films In the first series the central ray was at right angle to the film and in the second the central ray was directed 15° proximally Each series contained five films demonstrating the wrist in different degrees of pronation and supination (10°–5°–0°–5°–10°, Fig 1) This was accomplished by turning the tube of the skull table in a plane 90 to the long axis of the radius In all projections the central ray was directed towards the radio carpal joint

Measuring technique The ulnar inclination of the distal radial joint surface was measured in the postero-anterior view The material was grouped in cases with an ulnar inclination of more than 15° and cases with an ulnar inclination of 15° or less In the lateral projection single films not fulfilling the criteria for the series of 10°–5°–0°–5°–10° of pronation and supination were discarded The inclination of the radial joint surface in the lateral view was measured by the method of FRIBERG & LUNDSTRÖM The inclination was expressed as volar or dorsal inclination or tilt of the joint surface from a plane perpendicular to the long axis of the radius The distance between the dorsal contours of the radius and head of the ulna was measured In individual cases the change in relation found between the two bones was correlated with the difference in pronation or supination between the exposures

Statistical methods The variance and standard deviation of the measurements were calculated The Z-test was used to assess differences between the groups

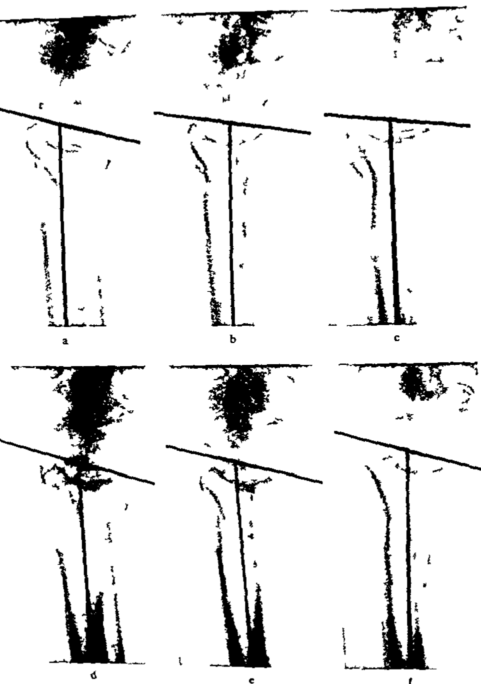


Fig. 1 Lateral views of the wrist in a case with a distal radial fracture with minimum radial compression (a, b, c) Perpendicular projections. (d, e, f) Central ray directed 15 proximally (b) and e) exact lateral projections a) and d) 5 of pronation c) and f) 5 of supination. The dorsal inclination of the joint surface is a) 14 b) 7 c) 5 d) 13 e) 14 f) 14

Table

Mean absolute difference in the inclination of the radial joint surface to the correct lateral projection (0°) Number of cases in parenthesis

Projection	10° pronation	5° pronation	0°	5° supination	10° supination
Total series					
Perpendicular	4 06°±SD 3 6°	2 45°±SD−1 04°	—	2 66°±SD—1 86°	3 02°±SD−2 55°
	(32)	(31)	—	(30)	(38)
Directed	2 45°±SD−2 33°	1 22°±SD−1 17°	—	1 22°±SD−1 05°	1 68°±SD−2 24°
15° prox	(33)	(31)	—	(31)	(35)
Cases with no or moderate radial compression					
Perpendicular	4 43°±SD 3 52°	2 75°±SD−2 04°	—	2 60°±SD−1 67°	3 25°±SD−2 22°
	(23)	(24)	—	(23)	(27)
Directed	2 04°±SD−1 79°	1 04°±SD−0 90°	—	1 08°±SD−0 92°	1 24°±SD−1 33°
15° prox	(23)	(24)	—	(24)	(25)
Cases with considerable radial compression					
Perpendicular	3 11°±SD−3 82°	1 42°±SD−1 13°	—	2 85°±SD−2 54°	2 45°±SD−3 26°
	(9)	(7)	—	(7)	(11)
Directed	3 4°±SD−3 16°	1 57°±SD−1 27°	—	1 71°±SD−1 38°	2 80°±SD−3 52°
15° prox	(10)	(7)	—	(7)	(10)

Results

Total series The mean absolute differences in joint surface inclination between the correct lateral views (0° rotation) and the views demonstrating the wrists in 5 and 10 degrees of pronation and supination were analysed (Table) At 5 degrees of pronation or supination the projection with the central ray angulated 15° proximally significantly (p=0 001 and 0 002, respectively) reduced the mean absolute differences compared to the perpendicular projection Similar results were observed when the angulated and perpendicular projections were compared in the views with the wrist at 10 degrees of pronation or supination (p=0 02 and 0 04, respectively) Ten degrees of pronation was further found to increase the mean absolute difference significantly (p=0 01 and 0 03, respectively) compared to the views with only 5 degrees of pronation of the wrist This difference was not observed between 5 or 10 degrees of supination The mean values of the joint surface inclination were found to be different in the two projections (Fig 2 a) Except for the view with the wrist at 10° of pronation the angled projection depicted the joint surface more dorsally inclined than the perpendicular projection (p>0 05 and 0 001, respectively) It was further observed that in the proximally directed projection a rotation of the wrist from pronation to supination resulted in an increased dorsal inclination of the joint surface The reverse situation was found in the perpendicular projection An assessment was also made of the degree of rotation of the wrist that was possible within the range of the criterion of an acceptable lateral projection, i e the head of the ulna superimposed on the distal part of the radius In all cases, this criterion for an acceptable lateral projection

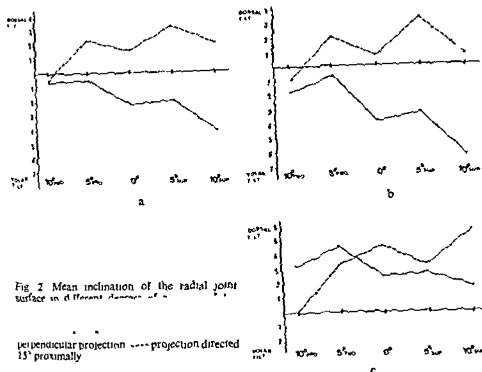


Fig 2 Mean inclination of the radial joint surface in different degrees of [illegible]

perpendicular projection ---- projection directed 15° proximally

permitted 10° to 15° of rotation of the forearm The distances between the dorsal cortical borders of the radius and the head of the ulna were measured to evaluate differences in rotation between two examinations A difference of 1° in rotation resulted in a mean difference in the distance of 0 44 mm $\pm$ SD = 0 12 mm In this respect no significant differences existed between the two projections used or between the different degrees of pronation or supination

Fractures with no or moderate radial compression The fractures with an ulnar inclination of the radial joint surface of more than 15° in the postero-anterior view were examined separately The mean absolute differences in joint surface inclinication between the correct lateral view and the views taken at different degrees of pronation and supination were found to be highly significantly reduced ($p = 0\ 001$) in the proximally directed projection compared to the perpendicular one The mean absolute differences in the projections directed proximally were further reduced in the present group compared to the result for the total series The reverse situation was found in the perpendicular projection (Table) The analysis of the mean values for the inclination of the joint surface resulted in similar findings to those in the total series Except for the view with the wrist at 10° of pronation, the proximally directed projection reproduced the joint surface of the radius more dorsally inclined than the perpendicular one ($p < 0\ 001$, Fig 2 b)

Fractures with considerable radial compression. This group comprised the fractures with an ulnar inclination of the radial joint surface in the postero-anterior view of 15° or less. The analysis of the mean absolute difference in the inclination found at different degrees of rotation demonstrated that no significant differences existed between the two projections (Table). In these cases the proximally directed projection depicted the joint surface more dorsally inclined ($p = 0.01$) only in the views supinated 10°. In the other projections the mean value of joint surface inclination did not differ (Fig. 2 c). Rotation of the wrist resulted in similar results to those in the total series. Increased supination increased the inclination of the joint surface in the dorsal direction in the proximally directed projection and increased the inclination in the volar direction in the perpendicular projection (Fig. 2 c).

Discussion

The criterion of an acceptable lateral projection of the radio-carpal joint is generally considered to be fulfilled when the distal part of ulna is superimposed on the radius. It is evident that this criterion allows differences in pronation or supination of the wrist between two examinations. In the present material it was found that the rotation possible within the limits of the criterion amounts to more than 10°. This finding showed the need for a method to estimate the difference in rotation of the forearm between two examinations. Analysis of the distance between the dorsal cortical borders of the radius and ulna showed that a rotation of 5° resulted in a change of approximately 2 mm in the relation between the two bones. It has been pointed out previously that small variations in pronation or supination alter the measured inclination of the distal joint surface of the radius (WIKLUND & MÜLLERN-ASPEGREN 1956). However, no systematic analysis exists concerning the effect of different degrees of rotation of the forearm on the measured inclination of the joint surface. The optimum projection for demonstration of and for measurements of the joint surface of the radius after distal radial fractures has still not been conclusively established. The major textbooks in diagnostic radiology indicate a projection with the central ray at right angles to the film. A direction of the central ray 25° proximally was recommended by PARKER & CULPEPPER (1946). However, this projection gives a distorted view of the distal part of the radius and does not seem to have been put into practical use. MOVIN & KARLSSON (1968) suggested that the central ray should have a proximal direction of 15° in cases with no fracture, but be perpendicular to the film plane in cases with known or possible fracture. FRIBERG & LUNDSTRÖM found that the proximally directed projection significantly improved the demonstration of the normal radio-carpal joint and the results of the measurements when compared to the perpendicular projection.

The present results demonstrate that when the perpendicular projection was used different degrees of rotation of the wrists resulted in considerable differences in the inclination of the radial joint surface. Thus, the difference in measured values in the

lateral perpendicular projection for the entire series averages 4 06° (Table), with a standard deviation of 3 6° this means that in individual cases the difference may amount to 15° with as small a difference in rotation as 10° In the total material the projection with the central ray directed 15° proximally highly significantly reduced the mean absolute differences in the radial joint surface inclinations compared to the perpendicular projections The increased accuracy of the measurements was even further increased in cases with no or moderate radial compression However, in the fractures with considerable radial compression no significant differences were observed between the two projections used The explanation of the difference in results between the proximally directed and the perpendicular projection is to be found in the fact that in cases with no or moderate radial compression the perpendicular projection is not tangential to the joint surface This projection then gives a less easily defined joint surface and measuring points than the proximally directed projection In cases with considerable radial compression both projections will be tangential to the joint surface and demonstrate the joint without major differences in exactness Rotation of the wrist from pronation to supination resulted in systematic changes in the inclination of the radial joint surface In the proximally directed projection the joint surface appeared with an increased dorsal inclination with increasing supination In the perpendicular projection increasing supination resulted in an increasing volar inclination of the joint surface These systematic changes in inclination cannot be explained by a purely geometric effect on the inclination due to the rotation The most probable explanation is that the rotation of the wrist changes that part of the joint surface demonstrated on the film, resulting in different measuring points FRIBERG & LUNDSTRÖM pointed out that in normal wrists a projection with the central ray directed 15° proximally depicts the joint surface more dorsally inclined than a perpendicular projection This is in agreement with the results found in the present cases with no or moderate radial compression This must be borne in mind in clinical practice so that only comparable projections are used However, in cases with considerable radial compression this tendency was only found in the views with the wrist at 10 degrees of supination

SUMMARY

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... the perpendicular projection The joint surface was depicted more dorsally inclined than in the perpendicular projection

ZUSAMMENFASSUNG

Vierzig Handgelenke mit einer Fraktur im distalen Teil des Radius wurden rontgenuntersucht Auf Seitenbildern wurde die Inklination der Gelenkfläche des Radius in verschiedenen Graden von Pronation und Supination untersucht Der Zentralstrahl war 15° Grad proximal gerichtet und die Resultate wurden mit denen verglichen wo der Zentralstrahl perpendikular gerichtet war In perpendikularen Aufnahmen konnten sogar kleine Differenzen in Pronation oder Supination die gemessene Inklination der Gelenkflache des Radius beeinflussen Die Projektion mit dem Zentralstrahl 15° proximal verminderte signifikant die Fehler zwischen den Messungen im Vergleich zu der perpendikularen Projektion Die Gelenkflache war mehr distal inkliniert dargestellt als in der perpendikularen Projektion

RÉSUMÉ

Les auteurs ont fait une radiographie de 40 poignets atteints de fracture de la partie distale du radius Sur le profil l'inclinaison de la surface articulaire radiale a été étudiée dans différents degrés de pronation et de supination Le rayon central était incliné de 15° en direction proximale et les résultats ont été comparés avec ceux qui sont obtenus avec un rayon central perpendiculaire Dans les incidences perpendiculaires, des différences meme modérées dans la pronation ou la supination entre deux examens peuvent modifier nettement l inclinaison mesurée de la surface articulaire du radius La projection faite avec une angulation proximale de 15° du rayon central diminue de façon très significative les différences entre les mesures par comparaison avec l'incidence perpendiculaire et donne de la surface articulaire une image plus inclinée en direction dorsale que la projection perpendiculaire

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THROMBORESISTANCE AND STABILITY OF A HEPARINIZED POLYMER

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Thrombus formation due to contact between circulating blood and foreign surfaces is a major drawback of many medical devices, and various methods have been elaborated to improve the biocompatibility of artificial materials The formation of a thrombus is a complicated process involving cross reactions between plasma proteins and platelets (SCARBOROUGH 1971) There is strong evidence (SALZMAN 1971) that the platelets play a central role in the reactions of the blood to foreign material Binding of heparin to polymeric surfaces by the method of ERIKSSON et coll (1967) and LAGERGREN & ERIKSSON (1971) has been shown to reduce the adhesion of platelets to the surface (JACOBSSON & SCHLOSSMAN 1973, LAGERGREN et coll 1974) in vitro as well as in animal experiments and this has been confirmed in a clinical trial of heparinized vascular catheters at coronary angiography (ELDH & JACOBSSON 1974) It was then discovered that the stability of the binding of heparin in contact with blood varied somewhat with the polymeric materials of which the catheters were made The heparinization process has therefore been modified to improve the stability Arteriovenous polyethylene shunts heparinized in this way have been inserted in dogs and the thromboresistant properties of the material have been assessed by scanning electron microscopy (SEM) The stability of the wall-bonded heparin has been determined by a thrombin clotting time assay

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Table

Heparin leakage from catheters heparinized by the original method of LAGERGREN & ERIKSSON *and by the modified stabilization procedure*

Exposure time of plasma to catheter (min)	Heparin leakage IU/cm² from the catheter surface	
	Original method n = 4	Modified method n = 4
20	0.26 ± 0.03	0.009 ± 0.001
60	0.26 ± 0.01	0.013 ± 0.001
90	0.28 ± 0.01	0.026 ± 0.003

Material and Methods

Polyethylene catheters, 80 cm long and with an inner diameter of 1.8 mm and an outer diameter of 2.8 mm (Portex PE 260) were used as shunts bilaterally between the femoral artery and vein in 5 mongrels. The shunt on one side was heparinized but not that on the other. In 3 of the dogs the shunts were fastened in such a position as to form a sinus curve in order to create a more irregular flow. In the other 2 dogs the shunts formed a single loop. After 20, 45 and 240 minutes, samples were excised for SEM. In between sampling the shunts were reconnected by insertion of the ends into an outer plastic muff.

Heparinization. The shunts were heparinized (Heparin, Vitrum, Stockholm, Sweden) by Aminkemi (Bromma, Sweden), according to the method described by LAGERGREN & ERIKSSON with a slight modification of the stabilization procedure to improve the stability of the heparin binding (ERIKSSON et coll.). The heparinization procedure results in a final heparin concentration corresponding to about one IU/cm² on the treated material.

The elution of heparin from the surface was measured in vitro by a thrombin clotting time test (EIKA et coll. 1972). An amount of 0.3 ml of human plasma, anticoagulated with 0.1 M sodium citrate in the ratio 1:10 was poured into catheters with an inner surface of 1 400 mm². The ends of the catheters were joined by an outer plastic muff, after which the catheters were placed around a cylinder on a slanting turntable rotating at 4 rpm. The concentration of heparin in the plasma was measured after 20, 60 and 90 min. The tests were performed by addition of 0.1 ml thrombin (3 NIH/ml) to 0.2 ml of the plasma sample prewarmed at 37°C. Catheters stabilized by the modified procedure were compared with catheters stabilized according to the original method.

Scanning electron microscopy. Immediately after the pieces of the shunts had been excised the blood was allowed to flow off, and the pieces were placed in a 3 % solu-


a


b


c

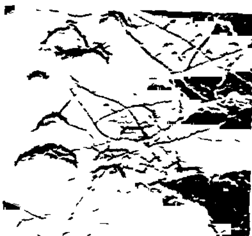

d

Fig. 1 SEM of polyethylene material a) before b) 20 m ... blood Large am... tact time the ... 4 h many strar... Probably pseuc...

tion of glutardialdehyde in phosphate buffer The pieces of the shunts were fixed at room temperature for 24 hours and air dried For SEM analysis these pieces were covered with a thin layer of gold in ...

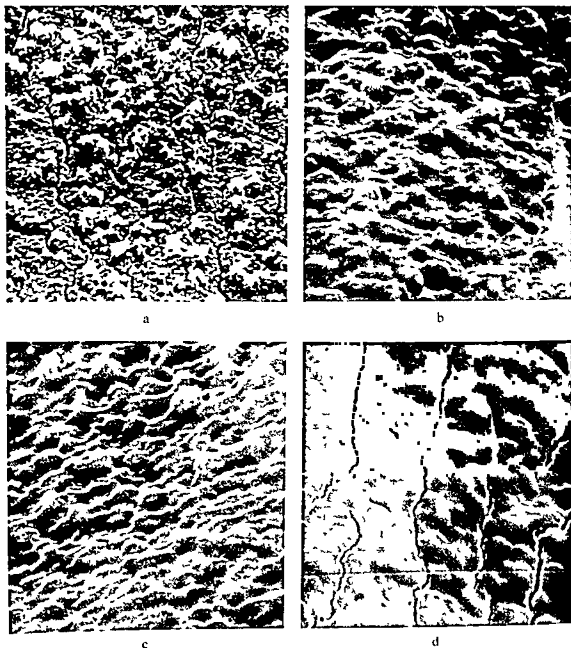


Fig 2 SEM of heparinized polyethylene material a) before b) 20 min c) 45 min and d) 4 h after contact with blood The heparinized surface has a marked granular appearance which after blood contact looks smoother Absence of any thrombus formation even after 4 h 8 300

Results

The stability of the heparin-binding was markedly improved by the modification of the stabilization procedure, as estimated from the in vitro tests The leakage of heparin from catheters stabilized according to the modified procedure was less than 10 per cent of that from catheters stabilized according to the unmodified procedure (Table) The leakage of heparin during rotation with plasma for 90 min in catheters

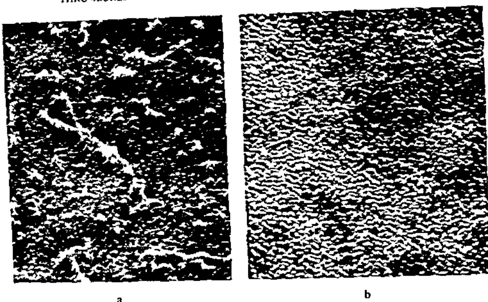
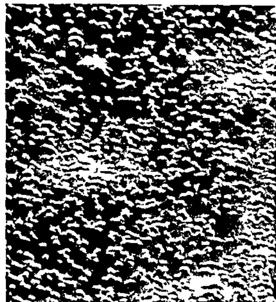


Fig. 3 Heparinized polyethylene material after blo
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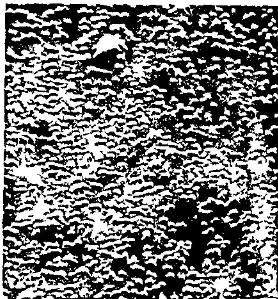
prepared by the modified procedure was estimated to be about 0 03 IU/cm², which corresponds to a few per cent of the total amount of heparin bound to the surface

SEM demonstrated that *already after 15* min the untreated material was covered almost entirely with platelets, partly discrete platelets and partly aggregates (Fig 1) Somewhat more thrombus formation seemed to appear in the sinus-shaped shunts The number of platelets that adhered to the surface did not vary significantly with time, but the proportion of aggregated platelets seemed to increase The platelets changed substantially in shape with time After 20 min most of the platelets were spherical but some were flattened On prolonged contact the platelets spread more and more and thereby increased their area of contact with the foreign surface This process was accompanied by a marked growth of platelet pseudopodes In some experiments long strands, sometimes crossing the platelets, occurred after 4 hours (Fig 1 d) Many of these strands could be traced to a platelet from which they seemed to extend and thereby to appear to be pseudopodes Other strands were not evidently connected with platelets and therefore probably consisted of fibrin Following contact with the blood, but not before, the catheters often exhibited thin cracks in an amorphous surface layer, which might indicate deposition of plasma components

Heparinized material, on the other hand, appeared to possess excellent thromboresistant properties as no definite platelets could be identified on any occasion in any of the dogs (Fig 2) In a few experiments some unidentified deposits were dem-



a



b

onstrated on the heparinized material (Fig 3 a), but these deposits were washed off by gentle rinsing with saline before fixation in glutardialdehyde (Fig 3 b) A similar rinsing did not significantly alter the appearance of the platelets on the untreated material (Fig 4) Moreover, the deposits did not resemble platelets in size or shape and were therefore regarded as artifacts Cracks in the heparinized surface were common both before and after exposure of the surface to the blood The heparinized surface originally had a marked granular appearance (Fig 3) After contact with the blood the granular structure gradually became less distinct and the finer details of the surface disappeared, but the basic structure of the heparin coating was still recognized after 4 hours (Fig 2)

Discussion

Many procedures have been elaborated to decrease the thrombogenicity of foreign material exposed to the blood stream GOTT et coll (1963) demonstrated that heparin could be bound to a graphite coated polymer surface and thereby decrease thrombus formation Several other methods for heparinization have since been described (AMPLATZ 1971, SALYER et coll 1971, GRODE et coll 1972, REMBAUM et coll 1973) and at present binding of heparin to surfaces appears to be the method of choice for foreign materials to be exposed for a short time to the blood (ELDH & JACOBSSON, HAWKINS & KELLEY 1973) However, it is difficult to compare the effects achieved by different means of heparinization due to lack of standardized methods for test-

ing thrombogenicity, although it is generally agreed (SALYER et coll, GRODE et coll, AMPLATZ, JACOBSSON & SCHLOSSMAN) that in vivo testing is of vital importance

Most of the heparinization methods have been tested in vivo during short (4 hours) exposure of the devices Using epoxy and urethane polymers containing heparin uniformly incorporated, SALYER et coll 'noted a slight degree of thrombus in various instances This could be attributed to the placement of the specimen in the vena cava' TANZAWA et coll (1973) used a hydrophilic polymer with a controlled release rate of heparin bound to cationic groups in the polymer and found little or no thrombus formation on inferior vena cava indwelling catheters AMPLATZ (1971) described a way of coating catheters with a benzalkonium heparin complex and found that such catheters 'delayed thrombus formation up to 1 hour in the vast majority of cases' In all these investigations the thrombus formation was evaluated macroscopically SEM has, however, been found to be a sensitive and suitable technique for analysing platelet activation (HOVIG 1970) as well as thrombus formation (DUTTON et coll 1968) ANDERSON et coll (1974) found that heparinization according to AMPLATZ prevented fibrin deposition during 30 min exposure, but not platelet adhesion or aggregation With the same technique REMBAUM et coll found that polyurethane with ionically bound heparin did not prevent platelet adhesion, but did decrease the rate of accumulation of platelets considerably during the first 30 min exposure in vivo

In the present experiments, SEM demonstrated extensive formation of thrombi on untreated material but none at all on the heparinized surface during 4 hours exposure in vivo

CRAMER et coll (1973) reported, that 80 per cent of their heparin coating (a benzalkonium heparin complex) was lost after one hour's exposure to the blood TANZAWA et coll measured the elution of heparin from their heparinized hydrophilic polymer as well as from the TDMAC heparin surface according to GRODE et coll They found that the TDMAC heparin surface had a high elution rate of heparin initially ($10\ 10^{-8}$ g/cm^2/min) which, however, decreased to $1\ 10^{-8}$ g/cm^2/min within 200 min The heparinized hydrophilic polymer was designed to release heparin at a constant rate above a critical level of $4\ 10^{-8}$ g/cm^2/min, a release rate which they considered necessary for maintenance of thromboresistance In the present experiments, the heparinized polymer was demonstrated to have excellent thromboresistant properties at such a low rate of heparin leakage as 0 2 10^{-8} g/cm^2/min

Despite minimal leakage of heparin, the heparinized surface used was free from thrombi after 4 hours exposure to blood It is therefore reasonable to assume that the thromboresistant properties of this surface are related to wall bonded heparin rather than release of heparin These findings are encouraging and warrant exploration of the possibilities of achieving longterm thromboresistance by means of a stable heparinized surface

SUMMARY

Untreated shunts and shunts heparinized according to a modification of the method of *Eriksson et coll* were inserted between the femoral artery and vein in mongrels. Scanning electron microscopy of pieces excised at different time periods of exposure to blood was performed The heparinized surface had excellent thromboresistant properties with no thrombus formation after 4 hours, while the untreated shunts were covered with platelets already within 20 min The leakage of heparin in vitro was less than 3 per cent of the total wall-bonded heparin during 90 min

ZUSAMMENFASSUNG

Unbehandelte und mit Heparin behandelte Shunts, entsprechend der Modifikation der Methode von Eriksson et coll, wurden zwischen die Arteria und Vena femoralis bei Hunden eingesetzt Eine Scanning Elektronenmikroskopische Untersuchung der zu verschiedenen Zeitpunkten nach Exposition durch Blut entnommenen Stücke wurde vorgenommen. Die Heparinbehandelte Oberfläche hatte ausgezeichnete thromboseresistente Eigenschaften ohne Bildung von Thromben nach 4 Stunden, während die unbehandelten Shunts schon innerhalb von 20 Minuten mit Thrombozyten bedeckt waren Der Austritt von Heparin in vitro war weniger als 3% der gesamten Wandgebundenen Heparinmenge innerhalb von Minuten

RÉSUMÉ

Des shunts non traités et des shunts héparinisés selon une modification de la méthode d'Eriksson et coll ont été placés entre l'artère et la veine fémorales sur des chiens auteurs ont examiné en microscopie électronique à balayage ces shunts retirés après périodes variables d'exposition au sang La surface héparinisée avait d'excellentes propriétés thromborésistantes sans formation de thrombus au bout de 4 heures alors que les shunts non traités étaient couverts de plaquettes au bout de 20 minutes La perte totale d'héparine in vitro est inférieure à 3% de l'héparine totale liée à la paroi pendant 90 minutes

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DOUBLE-LUMEN BALLOON CATHETER

R JENSEN and T OLIN

Balloon catheters of different types have been described and used for several years They have often been designed for a specific purpose (NORDENSTRÖM 1962), as flow-guided catheters for determinations of haemodynamics (DOTTER & LUKAS 1951) or as embolectomy catheters for vascular surgery (FOGARTY et coll 1963, FOGARTY & CRANLEY 1965) However, an all-round balloon catheter suitable for angiography has not been available Such a catheter has recently been developed in collaboration with A/S Surgimed in Denmark

Construction Like the catheters ordinarily used for angiography, the new catheter is made of low-density polyethylene It is a double-lumen catheter and the inside diameter of the small channel to the balloon is 0 8 mm whilst the large channel which passes through the balloon to the tip has an inner diameter of about 1 4 mm The outside diameter of the catheter is 2 6 mm except for the thickest part close to the balloon where it measures 3 0 mm The tip is tapered to an outside diameter of 1 4 mm The balloon is situated 4 2 mm from the tip, made of latex and fixed to the tube by two small rings of heat-shrinkable polyethylene (Fig 1) These rings fit into tracks on the catheter to secure the fixation of the balloon The balloon has a length of 8 mm and is connected to the thin channel in the catheter via two small side-holes The catheter is normally 90 cm long, but other lengths can be supplied on request The catheter is disposable and it is not possible to sterilize it in benzalkonium chloride or similar solutions since they will destroy the balloon

Supported by grant [illegible] Medical Research Council, Project No B75 14X (05 09B
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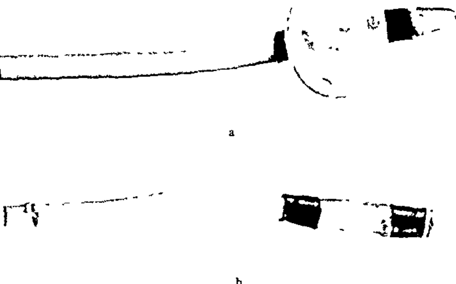


Fig 1 a) Balloon catheter, inflated b) When the catheter is straightened out the manoeuvering channel might be kinked off, if wrongly placed on the convexity of the pre bending

Technique The catheter can be moulded in hot water as is commonly done with the ordinary catheters of polyethylene The catheter should be bent slowly in hot water just below the boiling point and the manoeuvering channel to the balloon should be situated in the inner curve of the catheter To detect the channel, a copper thread may be introduced into the channel aimed at contrast injection, in strong light the manoeuvering channel can be identified Another possibility is to observe where the side-holes open into the balloon If the manoeuvering channel happens to be located in the outer curvature, and the catheter later is stretched out, the channel to the balloon may become kinked, making deflation next to impossible (Fig 1 b) Before insertion of the balloon catheter, the volume of contrast medium needed for sufficient filling of the balloon, under the conditions at hand, should be estimated For this purpose a 1 ml syringe, e g a tuberculine syringe with a piston diameter of 5 mm., is recommended. The volume normally required for occlusion of some of the larger arteries from the aorta varies between 0 2 and 0 8 ml That the balloon is sufficiently inflated can be felt on the piston of the syringe when the balloon reaches the wall of the artery The common technique for percutaneous insertion of a catheter can be used As a guide-wire a teflon-covered T-160 (A/S Surgimed, 120 cm long) is recommended, as it has low friction against the catheter, contrary to most other guide-wires The puncture of the femoral artery should not be made at right angles to the vessel but obliquely in order to facilitate the insertion of the catheter

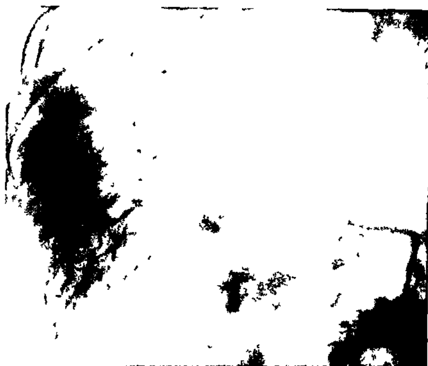


Fig 2 Hepatic arteriography with a balloon occlusion of the artery No dilution of the contrast medium in the arterial system

Since the quide-wire is relatively thin the support given to the catheter during the introduction is weak and therefore widening of the puncture hole with a grey catheter (Mediplast 2, soft grey, OD/ID = 2 8/1 4 mm) is recommended During introduction of the balloon into the desired vascular branch it is often suitable to fill the balloon partially, the bloodstream will then carry it into position

Application The catheter has been used experimentally in pigs and clinically in 10 patients Following its introduction into the femoral artery, different main branches of the abdominal aorta have been catheterized and temporarily occluded It was also possible to perform superselective catheterization of the hepatic artery The catheterized artery was occluded for about one minute, i e the time necessary for an angiography When contrast medium was injected peripherally to the occluding balloon, better filling of the arterial ramifications was achieved, facilitating the diagnosis No reactions from the patients were noted An angiography after the occlusion was removed, revealed no visible injury to the occluded vessel and no embolization

One patient (69 years old) developed a haematoma in the groin 12 days after the examination The haematoma was emptied and the puncture hole in the femoral artery was sutured Recovery was normal and no further complications occurred Obviously an atheromatous plaque had been punctured by accident in this case The caliber of the balloon catheter is somewhat larger than that of ordinary single

lumen catheters and a reduction in caliber is desirable Only introduction into the femoral artery of adults has been attempted Catheterization of small arteries such as those of children or the axillary artery of adults, is not to be recommended

Discussion

Several balloon catheters have been described previously The USCI catheter, Dotter Lukas No 1, is rigid and has a very large diameter (Dotter & Frisebe 1958) It appears to be intended only for experiments Edwards Laboratories (USA) make a double lumen catheter, according to Wholey (Gopalrov et coll 1972), with a circumference of 7 5 mm (7 5 F) The balloon attachment to the catheter is well made and from experience in dogs and humans, it has proved to be a reliable tool The shape of the catheter tip is also satisfactory and it is easy to percutaneously insert the catheter into the vessels The catheter is made of polyvinyl, which makes it possible to glue the balloon, but it has a bad 'memory' This means that the catheter does not retain a preformed curve after introduction into the bloodstream, it has therefore been reinforced with a steel thread cast into the catheter wall However, this limits its application and makes it too stiff for several types of work In our experience it is possible to catheterize only the large vessels and merely close to their origin from the aorta Another catheter of Edwards Laboratories, the Swan Ganz flow-guided catheter, is available in different dimensions This catheter is not reinforced and is flexible It is intended for flow-guided catheterization of the right heart and the pulmonary arteries from a peripheral superficial vein Selective catheterization of the abdominal arteries with this balloon catheter is next to impossible

The new catheter described is made of low-density polyethylene, which has a relatively good 'memory', i e it will retain a preformed curve relatively well after introduction into the bloodstream This makes it possible to perform superselective catheterization of the different arteries from the aorta, for example the common hepatic artery

SUMMARY

Description of a double lumen catheter with balloon suitable for catheterization and occlusion of different abdominal branches from the aorta

ZUSAMMENFASSUNG

Die Verfasser beschreiben einen neuen Doppel Lumen Katheter mit Ballon, der fur die Katheterisierung und den Verschluss verschiedener abdominaler Äste der Aorta geeignet ist

RÉSUMÉ

Description d un nouveau cathéter à double lumière avec ballonnet destiné au catheterisme et à l occlusion de différentes branches de l aorte abdominale

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I DIE AXIALE COMPUTER TOMOGRAPHIE DES GEHIRNSCHÄDELS Anwendungsmöglichkeiten und klinische Ergebnisse By E Kazner, W Lanksch, H. Steinhoff and J Wilske Sonderdruck aus der Zeitschrift Fortschritte der Neurologie-Psychiatrie und ihrer Grenzgebiete 92 pages with 136 illustrations and 5 tables Georg Thieme Verlag, Stuttgart 1975 Price DM 36 —

This booklet is a report on experiences of computer tomography (CT) with the EMI scanner, first generation, 160 × 160 matrix, from the neurosurgical unit of the Ludwig-Maximilians Universität in Munich, based on 1 060 examinations in 939 patients

About one quarter of the volume deals with the physical basis of CT, methodology and handling of the scanner, evaluation of CT images, the use of contrast media and artifacts In the remainder the pathology is presented under the subheadings Cerebral tumors (with discussion of differential diagnosis and some emphasis on oedema), Cerebro-vascular disorders, Cerebral atrophy, Trauma, Neuro-pediatric disorders and malformations, Inflammatory lesions and Orbital lesions This seems to be representative of the routine load in the average neurologic unit, with the exception of adult hydrocephalus, which is not discussed as a separate entity but touched upon briefly in various contexts Some of the case [illegible]

II COMPUTED TOMOGRAPHY OF THE BRAIN AND ORBIT (EMI SCANNING) By Paul F New and William R Scott 486 pages with 303 illustrations, 12 tables and 4 dual templates Williams & Wilkins, Baltimore, 1975 Price $ 39 50

This presentation by Paul New of Harvard and William Scott of Stanford represents rather a text-book approach to the subject of cranial computer tomography (CT) Part I consists of separate chapters on Historical background, General description of the EMI scanner, Patient positioning Physical considerations and Anatomic correlations, while Part II comprises an atlas of pathology (including consideration of the comparative value of CT and traditional neuroradiologic procedures) with the subheadings Gliomas, Meningiomas, Pituitary adenomas and craniopharyngiomas, Acoustic neuromas, Pineal area tumors, Miscellaneous primary neoplasms, Benign cysts, Metastatic intracranial neoplasms, Lymphomas, Blood, Intracerebral, intracerebellar and intraventricular hemorrhage, Extracerebral hematomas, Aneurysms, Arterio-venous malformations and vein of Galen aneurysm, Infarcts, Inflammatory disease, Obstructive hydrocephalus (nontumorous), Cerebral atrophies Developmental abnormalities Neuroectodermoses [illegible] CT scans with intra- [illegible]

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Various names have been marketed for the new tomographic roentgen technique A present the denomination "Computed tomography" seems to be favoured by many How ever, in view of the existence and development of computer assisted image reconstruct in the fields of emission radiology, using gamma as well as positron emitting radio and ultrasound, a more specific term may be necessary in order to define the technique CT in transmission radiology.

Another terminologic question of some consequence is the rather loose habit of using word 'density', adding a further concept to the already existing physical and photogra meanings of the word 'Attenuation' or 'absorption' levels seem to be more useful and pr terms for defining structural differences as registered by CT. Density should perhap reserved for use in the term electron density in CT, cf Rutherford et coll

The task of writing a comprehensive survey of a subject in such a vital dynamic sta development as CT at the present time is, of course, not just feasible, as too much c material will appear obsolete at the time of distribution in print (a situation that fa the condensed report at the expense of the text-book format) Nevertheless, the ne such surveys is obvious, not least for those taking up the new diagnostic technique Ven an opinion at this particular stage of the art of CT, I would rather consider the cond report by Kazner et coll the better buy of these two books, and hopefully wait for a edition, with improved resolution illustrations and better quality reproduction, of the by New & Scott

Ulf Ben

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